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MINISTRY OF FINANCE, EGYPT.

SURVEY DEPARTMENT.

A REPORT

ON THE

DELIMITATION OF THE TURCO-EGYPTIAN BOUNDARY,

BETWEEN THE VILAYET OF THE HEJAZ AND THE PENINSULA OF SINAI.

(June-September, 1906.)

BY

E. B. H. WADE,

together with additions by

B. F. E. KEELING AND J. I. CRAIG.

SURVEY DEPARTMENT PAPER No. 4.

Price 150 Milliemes.

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THE DELIMITATION

OF THE

TURCO-EGYPTIAN BOUNDARY, IN 1906.

MINISTRY OF FINANCE, EGYPT.

Egypt

SURVEY DEPARTMENT.

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INTRODUCTION.

This Report contains a detailed account of the operations which were carried out for delimiting a boundary between Turkish and Egyptian territory in the east of the Sinai Peninsula.

It was necessary that the operations should be completed as rapidly as possible and that the results should be of considerable accuracy but the local conditions in the summer months rendered it impossible to employ a network of triangulation points. The frequent dust-haze, the unsteadiness of marks seen over the heated surface of the desert, the distortion of natural objects by mirage, and other difficulties due to working on a heated desert plateau, rendered it necessary to employ such special methods as would reduce the errors due to these special conditions as much as possible. It was therefore decided to determine the latitude of a number of intervisible points and the azimuths of the lines joining them; then to obtain the longitude of the terminal point at Rafa by exchanging chronometer signals telegraphically with the Helwan Observatory near Cairo.

As this piece of work represents a modification of the ordinary methods in order to meet the special local conditions, it has seemed desirable to record in detail the methods used, the operations performed, and to indicate the probable degree of accuracy attained, in the hope that it may be of interest to others who may have to delimit boundary lines under similar conditions.

In the present case, a line of 210 kilometres was delimited in 31 days, 14 points being fixed. The demarcation by permanent signals, which have since been replaced by masonry marks, occupied 15 days.

The topography of as wide a belt as possible was also included, but, owing to the rate of movement, this seldom exceeded about 10 kilometres.

The total cost of the survey operations, including the determination of the 14 points and the marking of them permanently but not including the permanent masonry marks nor the transport of camp equipment, etc., amounted to L. E. 460.

H. G. Lyons,
Director General.

TEXT OF THE AGREEMENT DEFINING THE TURCO-EGYPTIAN BOUNDARY*.

THIS IS THE AGREEMENT, SIGNED AND EXCHANGED AT RAFAH ON (13 SHABAN, 1324; 18TH AILUL, 1322) 1ST OCTOBER, 1906, BETWEEN THE COMMISSIONERS OF THE TURKISH SULTANATE AND THE COMMISSIONERS OF THE EGYPTIAN KHEDIVIATE, CONCERNING THE FIXING OF A SEPARATING ADMINISTRATIVE LINE BETWEEN THE VILLAYET OF HEJAZ AND GOUVERNORATE OF JERUSALEM, AND THE SINAI PENINSULA.

El Miralai Staff Officer Ahmed Muzaffer Bey and El Bimbashi Staff Officer Mohamed Fahmi Bey as Commissioners of the TURKISH SULTANATE, and Emir el Lewa Ibrahim Fathi Pasha and El Miralai R. C. R. Owen Bey as Commissioners of the EGYPTIAN KHEDIVIATE, having been entrusted with the delimitation of the ADMINISTRATIVE SEPARATING LINE between the Villayet of HEJAZ and the SINAI PENINSULA, have, in the name of the TURKISH SULTANATE and the EGYPTIAN KHEDIVIATE, agreed as follows:—

ARTICLE 1.

The ADMINISTRATIVE SEPARATING LINE, as shewn on map attached to this AGREEMENT, begins at the point of RAS TABA on the western shore of the GULF of AKABA and follows along the Eastern ridge overlooking WADI TABA to the top of JEBEL FORT, from thence the SEPARATING LINE extends by straight lines as follows:—

From JEBEL FORT to a point not exceeding two hundred metres to the east of the top of JEBEL FATHI PASHA, thence to that point which is formed by the intersection of a prolongation of this line with a perpendicular line drawn from a point two hundred metres measured from the top of JEBEL FATHI PASHA along the line drawn from the centre of the top of that hill to MOFRAK POINT (the MOFRAK is the junction of the GAZA-AKABA and NEKHL-AKABA roads). From this point of intersection to the hill east of and overlooking THAMILET EL RADADI—place where there is water—so that the THAMILA (or water) remains west of the LINE, thence to the top of RAS RADADI marked on the above mentioned map as A. 3., thence to top of JEBEL SAFRA marked as A. 4., thence to top of eastern peak of UM GUF marked as A. 5., thence to that point marked as A. 7. north of THAMILET SUEILMA thence to that point marked as A. 8. on west-north-west of JEBEL SEMAUI, thence to top of hill west-north-west of BIR MAGHARA (which is the well in the Northern branch of the WADI MA YEIN, leaving that well east of the SEPARATING LINE), from thence to A. 9., from thence to A. 9. *bis* west of JEBEL MEGRAH, from

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[*] *Journal Officiel,* No. 127, November 10, 1906.

thence to RAS EL AIN marked as A. 10. *bis*, from thence to a point on JEBEL UM HAWAWIT marked as A. 11., from thence to half distance between two pillars (which pillars are marked as A. 13.) under a tree three hundred and ninety metres south-west of BIR RAFAH, it then runs in a straight line at a bearing of 280° of the magnetic north (viz., 80° to the west) to a point on a sand hill measured four hundred and twenty metres in a straight line from the above mentioned pillars, thence in a straight line at a bearing of 334° of the magnetic north (viz., 26° to the west) to the MEDITERRANEAN SEA passing over hill of ruins on the SEA SHORE.

ART. 2.

The SEPARATING LINE mentioned in Artcle 1 has been indicated by a black, broken line on duplicate maps (annexed to this AGREEMENT), which shall be signed and exchanged simultaneously with the AGREEMENT.

ART. 3.

Boundary pillars will be erected, in the presence of the Joint Commission, at intervisible points along the SEPARATING LINE, from the point on the MEDITERRANEAN SHORE to the point on the SHORE of the GULF of AKABA.

ART. 4.

These boundary pillars will be under the protection of the TURKISH SULTANATE and EGYPTIAN KHEDIVIATE.

ART. 5.

Should it be necessary in future to renew these pillars, or to increase them, each party shall send a representative for this purpose. The positions of these new pillars shall be determined by the course of the SEPARATING LINE as laid down in the map.

ART. 6.

All tribes living on both sides shall have the right of benefiting by the water as heretofore, viz., they shall retain their ancient and former rights in this respect.

Necessary guarantees will be given to Arab tribes respecting above.

Also TURKISH soldiers, NATIVE individuals and GENDARMES shall benefit by the water which remained West of the SEPARATING LINE.

ART. 7.

Armed TURKISH soldiers and armed GENDARMES will not be permitted to cross to the west of the SEPARATING LINE.

ART. 8.

Natives and Arabs of both sides shall continue to retain the same established and ancient rights of ownership of waters, fields and lands on both sides as formerly.

Commissioners of the
Turkish Sultanate.
(sd) Miralai Staff Officer
MUZAFFER,
(sd) Bimbashi Staff Officer
FAHMY.

Commissioners of the
Egyptian Khediviate.
(sd) Emir Lewa IBRAHIM FATHI.
(sd) Miralai R.C.R. OWEN.

DELIMITATION OF THE TURCO-EGYPTIAN BOUNDARY.

1.—INSTRUCTIONS.

On February 25, 1906, I received instructions to proceed with an expedition which was on the point of starting to delimit a frontier line between Turkey and Egypt where the Vilayet of the Hejaz joined the peninsula of Sinai. I was to determine as accurately as possible the latitude and longitude of any points indicated by the Commissioners and to carry out such topographical operations as time permitted.

On March 7 the work was postponed pending negotiations; and on May 19 fresh orders were issued, and Mr. B.F.E. Keeling was placed in charge of the topographical part of the work. He reports separately on the map which he prepared and which was adjusted to the astronomical positions which I determimed.

2.—PROGRAMME.

It was determined that the general basis of the survey should be a traverse by the method of latitude and azimuth, that a longitude should be fixed at the south end of the traverse by transport of chronometers from Suez, and another at the north end by exchange of telegraphic signals between Rafa and Helwan observatory ; also that control longitudes in the field should be determined by the chronometers, in case circumstances should arise unfavourable to the determination of longitude by the method of latitude and azimuth.

3.—EQUIPMENT.

The equipment consisted of an 8-inch Troughton and Simms theodolite with reading microscopes, a sextant reading to 10″, an artificial horizon, and 5 chronometer watches by Usher and Cole. The party assisting me in astronomical observations included my assistant and three chainmen.

4.—METHODS EMPLOYED.

The determination of latitude and local time was in nearly all cases effected by the method described by me in Monthly Notices of the Royal Astronomical Society (Vol. LXIV. No. 2, Dec. 1903) which has long been in use in the triangulation of Egypt, and has also been adopted by Mr. Cooke, the Government astronomer of Australia.

Simplifications in the computation adapted for field use are described on p. 16. In a few cases the sun's altitude near the prime vertical was employed for time observations. For the measurements of azimuths, pointings to Polaris were nearly always used, but in a few cases I have employed observations of the sun.

5.—OUTLINE OF DELIMITATION OPERATIONS.

The general course of the operations will be made clear by a few preliminary remarks, followed by the substance of three interim reports made from the field to the Director General of the Survey Department, and the actual journal of the work. The first intimation to hold myself in readiness was received May 16 by telegram, and as it was anticipated that a start would be made in three days, preparations were actively pursued and I was prepared by May 19. In fact we were not required to leave till the 22nd and a further interval of three days intervened before the whole party mustered at Suez and sailed in H. H. S. "Nur el Bahr" for Aqaba. These three days were used in rehearsals, and especially in the determination of local time at Suez at which station the accurate longitude has been fixed (see p. 87). A good passage was made from Suez to Taba by the "Nur el Bahr," under the command of El Bimbashi Potts. In the evening of the 26th we anchored off Farun Island near Taba; the next morning the party was landed at Taba and I determined local time by altitudes of the sun both a.m. and p.m. In the evening I rejoined the main party at Aqaba where the main caravan was in readiness, having come down from Jerusalem via Hebron and Beersheba. While at Aqaba I made further observations for latitude, time, and azimuth, and carried out some topography on the east shore of the gulf and in the district to the north-west. These operations have been incorporated in the map. The advance then began, and the general plan was as follows. The heavy caravan travelled on the whole by the Ghaza road, while the astronomical party branched off to camp at the astronomical stations. They travelled very light, equipped with only one small tent, and slept on the ground, as it was necessary to move rapidly on account of scarcity of water. Junctions with the main party were effected at Mayein which is situated about midway between the Gulf of Aqaba and the Mediterranean; at Qoseima; at el Auga; and at Rafa. Mr. Keeling proceeded in advance of me, and with the help of a prismatic compass and an invaluable Bedawi guide, Sheikh Dawfalla, was able to select points lying for the most part near the straight line joining the north corner of the Gulf of Aqaba and Rafa, which had been agreed on in the course of the negotiations, as the approximate frontier.

Aqaba, May 29, 1906.

DIRECTOR GENERAL, SURVEY DEPARTMENT,

As the "Nur el Bahr" is leaving with despatches to-morrow morning, I take the opportunity to report progress to date. I left Cairo for Suez on the 22nd inst. with all necessary baggage, the heavier portions being sent on the night before. I observed at Suez every night that I was there, and connected my position with the one determined by Sir David Gill. The value obtained for the difference of longitude from Helwan to Suez was satisfactory, which promises well for future differences. The five chronometers which I have with me are compared daily which affords a check on their rate.

We sailed from Suez on the 25th inst.

We made the entrance to the Gulf of Aqaba at daylight on the 26th and anchored off the island called Geziret el Farun at 5 p.m. I arranged to be set on shore at Taba early next morning, and determined local time by the sun's altitude a.m. and p.m., the observations being very successful. On the evening of the 28th inst. I determined the azimuth of a line 500 metres in length at Aqaba, and Mr. Keeling who has been carrying a tacheometric survey from Taba to Aqaba, joined on to it. I have so far observed a complete set at Suez (comprising all classes of observation) a longitude at Taba, and an azimuth at Aqaba. I am on the point of returning to Taba to set up a small camp there to complete the astronomical observations at that point.

(*Signed*) B. H. WADE.

After sending off this report I moved with a small camp to Taba to continue astronomical observations. It should be explained that the preliminary visit to Taba on the 27th was made in order that local time might be observed as early as possible after the date of leaving Suez, as every day increased the possible accumulation of chronometer error. But it was necessary to join the main camp at Aqaba as soon as local time was fixed at Taba. As the work at Taba was fairly typical of other stations I will describe the procedure in detail. The theodolite was set up at the same point as had been used in the observations for local time on the 27th, on the sandy flat at the mouth of Wadi Taba. Shortly after sunset the instrument was pointed to Polaris and the time of its transit over the horizontal wire, was noted by the watch A (which was invariably used in the field). After Polaris had passed, the instrument was rotated in azimuth, but always clamped at the original altitude, and the times of transit of several other stars were observed. The programme of stars was selected so as to include two stars near the prime vertical and others near the north and south meridians.

From the times of transit and level readings the latitude of the place and chronometer correction are found by the methods described on p. 16. The latitude set being finished, the theodolite was turned to Polaris and the horizontal verniers were read, and also the time. It was then turned to the azimuth lamp and the verniers read again. The azimuth of the lamp follows by the usual computation.

Mayein, June 14, 1906.

DIRECTOR GENERAL, SURVEY DEPARTMENT,

Between June 1st and 4th there was an interval in which the expedition was waiting for despatches, and I used this to make a sketch map of Wadi Taba and Wadi Tueiba finishing along the Nekhl road. [This work has been incorporated in the general map]. Meantime the main camp having received the despatches moved to their first halt at Mufrak point, which is within easy reach of the well at Gebel Radadi. I rejoined them with my sketches at this point, and determined the coordinates of a site on Gebel Radadi. After this the main caravan pursued the Ghaza road while the survey party travelled by a more easterly route via the well Ghabia and the Wadi Gerafi at which places there is water. Astronomical stations were occupied at Gebel Bir Said, Gebel Um Quf, Gebel el Qeradi. Mr. Keeling went on one day in advance of me so as to indicate suitable sites for astronomical stations. It was intended to occupy next a small conical hill marked A_7 on the map, a little east of Thamelet Swelma, but two circumstances led us to press on into Mayein, which is a day's march to the north. The first was that Mr. Keeling's party was interrupted by armed Bedawin to the number of 150 who, it appeared later, were on a foray against the Haiwat tribe with whom they had a feud. The marauders fortunately withdrew, after restoring the baggage which they had temporarily seized. The other reason was that stores were low, the earlier part of the route from Gebel Radadi having proved more arduous than was expected. Early in the morning of June 13 we reached Mayein, and found the main camp pitched in the middle of a flat basin surrounded by hills. From Mayein Mr. Keeling started on a rapid reconnaisance as far as Qoseima, with a view to settling provisionally at any rate, the vexed question whether Ain Qadis and Ain Qoseima are west or east of the treaty line. Meanwhile I determined the longitude of Mayein provisionally by means of chronometers, for it will be understood that the necessity for marching into Mayein without occupying the station at A. 7., had temporarily interrupted our chain of longitude. We have in all seven accurately established astronomical points and shall have eight when the hill at A. 7. has been occupied. The astronomical observations are computed at once and I have been able to keep them strictly up to date, although the computations are somewhat elaborate. This has been necessary, as constant enquiries are made by the Turkish commissioners as to the position of points.

(*Signed*) B. H. WADE.

After forwarding this report, I continued to observe at Mayein and also took a complete set at point A. 8. on Gebel Semawi which is practically the central point of the traverse. I then returned to A. 7. and made the usual observations. I was able to sight A. 6. and A. 8. so that the chain was complete. Mr. Keeling now returned to camp in Mayein, and his sketches left no doubt that both Ain Qadis and Qoseima must be well to the west of the treaty line.

On June 21 the caravan left Mayein en route for Ain Qadis where they camped that night. The astronomical party branched off at Wadi Lussan and climbed on to Gebel Kharuf (referred to in the diary as Gebel Raman the name used by Sheikh Abu Kasin our Bedawi guide, who however was not so reliable as Sheikh Dawfalla). We were accompanied by Mr. Keeling who took some prismatic compass sights and also by the commissioners on both sides. In the afternoon they left Gebel Kharuf via the Wadi Ain Qadis to rejoin the caravan. We camped on the south edge of the plateau of Gebel Kharuf from which station A. 8. is plainly visible, and fixed a new position A. 9. We were unable however to see more than a few kilometres to the north owing to the character of the ground. Next forenoon accordingly was occupied in fixing another point A. 9. *bis*, 5 kilometres to the north-west and with a clear view northwards towards Qoseima. For this purpose a small base was measured and angles observed to A. 9. In the afternoon we descended Ain Qadis and emerged on the level plain into which it drains. We pursued our way as far as possible till sunset, then camped and reached Qoseima early next morning where we found the caravan. The same afternoon we proceeded up the Wadi Ras el Ain. Already the signs of cultivation due to an increased winter rainfall were evident. With considerable difficulty we reached, just before sunset, Gebel Ras el Ain a point chosen by Mr. Keeling as likely to be suitable. We were doomed to disappointment, as the last point A. 9. *bis* was hidden by the north-eastern shoulder of Gebel Kharuf. I regret now that this shoulder was not chosen instead of A. 9. *bis*, as its square top forms a marked feature visible practically all the way to Rafa. As it was we had to turn back, and next morning occupied another hill at Ain el Quderat: from this point we were able to see A. 9. *bis* clearly and connected it, using an azimuth to the sun. Hence we descended once more into the plain, and marching all day arrived at el Auga.

After a day's rest at el Auga we moved west to the hill Gebel Um Hawawit where we made our astronomical station A. 11. From this we were able to see Ras el Ain, but not Ain Quderat as had been confidently hoped. The position of Ras el Ain had, however, been fixed by Mr. Keeling relatively to Ain Quderat from which it is distant only 6 kilometres, so that it was possible to dispense with observations to A.10. (Ain Quderat). The observations complete, we walked back into camp at el Auga, a distance of 3 kilometres, by moonlight. The task proved much more difficult than was anticipated, but we found our way in at about midnight. Early next morning we separated from the caravan for the last time before finally rejoining them at Rafa. At noon we camped at the foot of Khashm el Qarn, and observed from its summit at night. We marched till 3 p.m. the next day, and arrived at Rafa. On arriving at Rafa it was found that a telegraphic installation had been set up in a tent, and all was in readiness for the exchange of signals with Helwan observatory. On the night of June 30, observations were made for local time and latitude at a point A.13., 80 metres south of the marble pillars, which had been restored to their original position. Signals were successfully exchanged in three groups, with Mr. Craig at the Helwan observatory. I also determined the azimuth of a mark (C in the sketch of p. 40) which formed a point in a triangulation executed by Mr. Keeling, enabling a connection to be made with A.12. In the next 24 hours the whole of the computation was brought up to date so that I was able to furnish the latitude and longitude of all points to the Commissioners. Mr. Keeling had already left for El Arish, where a drawing office was arranged in the fort. Here he was met by Mr. Hayes, a draughtsman in the Survey Department, and the work of producing a finished map was at once begun. Before he left I had supplied him with the latitude and longitude of the astronomical stations adjusted to a provisional origin, and as soon as the telegraphic longitude was finished I telegraphed in to him the data for the final positions. On July 2 I left for El Arish and arrived there next day. Here I confirmed the values telegraphed, and worked up the portions of topography which I had executed myself. They were incorporated in the map which was completed by July 6. During my stay at El Arish I computed the points of a rhumb-line joining Marashash (on the north corner of the Gulf of Aqaba) and Rafa, and this was plotted on the chart in red, We then returned to Rafa. Mr. Keeling was shortly recalled to Cairo sailing by H. H. S. "Abd el Moneim." A prolonged conference between the commissioners now began which ended in the signature of the treaty on Oct. 1. Though my active duty terminated at the departure from El Arish on July 6, I was retained at Rafa for another month, in case my services should be required. I finally sailed for Alexandria on Aug. 3.

List of astronomical stations occupied:—

A. 1. On the beach at Taba close to B. 1.
B. 1. Conspicuous granite knob on shore at Taba.
A. 2. On the north shore of Gulf of Aqaba.
A. 3. Ras el Radadi.
A. 4. A peak of Gebel Safra near Bir Said.
A. 5. Gebel Um Quf.
A. 6. Gebel Abu Qeradi.
A. 7. Conical hill between Thamelet el Swelma and junction of Wadi Um Halluf and Wadi Gerafi.
A. 8. Conspicuous detached peak west of Gebel Semawi.
A. 9. and A. 9. *bis* on Gebel Kharuf.
A. 10. Ras el Ain el Quderat.
A. 10. *bis*. Ras el Ain.
A. 11. Gebel Um Hawawit.
A. 12. Khashm el Qarn.
A. 13. On plain 80 metres due south of marble frontier pillars at Rafa.

6.—COMPUTATIONS.

The section which follows gives an explanation of the computations made in the field, which led to the latitudes and longitudes used in drawing the treaty map. I omit those calculations which deal with the determination of longitude by transport of chronometers overland. Longitudes obtained in that way are not sufficiently accurate to compete with those obtained by telegraph or by the method of latitude and azimuth. I include, however, the determination of the longitude of Taba by the transport of chronometers over sea from Suez.

(a) *Azimuths.*—Astronomical stations are denoted by the symbols A.1, A.2, etc. Lamp stations by L.1, L.2, etc. The azimuths have all been calculated by the formula:—

$$\cot A = \tan \delta \cos \varphi \operatorname{cosec} t - \sin \varphi \cot t.$$

Where Polaris is used small errors in the correction of the chronometer are insignificant, and as the azimuth was the first element to be calculated, the correction of the chronometer employed often differed somewhat from that ultimately found on reducing the observation for local time. It has not been found necessary to recompute any azimuths on this account. On the few occasions when the sun was used for azimuth the local time was specially found from its altitude first. The azimuth of the sun or star being known we at once have that of the lamp and thence that of the traverse line. When the sun is used, or when the Pole Star has been observed by daylight, we pass directly to the azimuth of the traverse line without the intervention of a lamp station. An azimuth observed at Suez and one at Taba are not shewn below as they do not enter into the computation of the traverse.

AZIMUTH AT STATION. A. 2.

	h.	m.	s.	
Mean Reading of Watch	5.	21.	32·38 [*]	
Approximate L. S. T.	12.	16.	16	
R. A. of Polaris	1.	24.	49·2	
Hour angle (arc)	17°	08'	18"	
Declination	88°	48'	04"·2	
Azimuth of Polaris	0°	24'	28"	W of N
Mean Circle on Polaris	2°	02'	32"·13	
Meridional Reading	2°	27'	00"·13	
Mean Circle on L. 2.	309°	27'	50"·25	
Azimuth of L. 2.	52°	59'	09"·83	W of N
	127°	00'	50"·17	W of S
Angle L. 2. to B. 1.	65°	37'	39"·75	
Azimuth A. 2. B. 1.	61°	22'	10"·50	W of S

AZIMUTH AT STATION. A. 3.

	h.	m.	s.	
Mean Reading of Watch	5.	03.	43	
Approximate L. S. T.	12.	29.	26	
R. A. of Polaris	1.	24.	56	
Hour angle (arc)	13°	52'	30"	W of N
Declination	88°	48'	03"	
Azimuth of Polaris	0°	19'	38"	W of N
Mean Circle on Polaris	0°	05'	40"	
Meridional Reading	0°	25'	18"	
Mean Circle on L. 3.	19°	46'	40"	
Azimuth of L. 3.	19°	21'	22"	E of N
„ „	199°	21'	22"	W of S
Angle L. 3. to A. 2.	+118°	15'	19"	
Azimuth A. 3. A. 2.	317°	36'	41"	„
Angle L. 3. A. 4.	− 42°	48'	16"	
Azimuth A. 3. A. 4.	156°	33'	06"	„

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[*] The computations which follow were made in the field and the results handed in on July 2, 1906. I am obliged to print them exactly as made, in order that the reader may see how the results handed in were obtained. This accounts for the fact that strict uniformity has not been maintained in some minor details, such as the number of decimal places exhibited.

1906, June 9d. 3h.

AZIMUTH AT STATION A. 5.

	h. m. s.	
Mean Reading of Watch	2. 32. 47	
Slow on L. M. T.	2. 32. 52	
L. M. T.	5. 05. 39	
Sun's hour angle...	46° 42'	
„ Azimuth	87° 57' 30"	from N
Mean Circle Reading on Sun	94° 08' 28"	
Meridional Reading	182° 05' 58"	on N
„ „	2° 05' 58"	on S
Mean Reading on A. 4....	356° 27' 49"	
Azimuth A. 5. A. 4.	354° 21' 51"	

AZIMUTH AT STATION A. 6.

	h. m. s.	
Mean Reading of Watch	4. 56. 32	
Approximate L. S. T....	12. 41. 00	
R. A. of Polaris	1. 25. 00·5	
Hour angle (arc)...	180°-11° 0' 00"	
Declination	88° 48' 02"	
Azimuth of Polaris	0° 15' 40"	W of N
Mean Circle on Polaris...	181° 52' 46"·5	
Meridional Reading	2° 08' 26"·5	on S
Mean Circle on L. 6.	135° 41' 30"·3	
Azimuth of L. 6....	133° 33' 03"·8	
Angle A. 5. to L. 6.	—144° 04' 22"	
Azimuth A. 6. A. 5.	349° 28' 41"·8	W of S

Azimuth at Station A. 7.

	h. m. s.	
Mean Reading of Watch	6. 33. 35·5	
Approximate L. S. T.	14. 52. 56	
R. A. of Polaris	1. 25. 07	
Hour angle (arc)	21° 57′ 15″	
Azimuth of Polaris	0° 30′ 03″	E of N
Mean Circle on Polaris	182° 22′ 53″	
Meridional Reading	181° 52′ 50″	on N
„ „	1° 52′ 50″	on S
Mean Circle Reading on L. 7.	308° 35′ 32″	
Azimuth of L. 7.	306° 46′ 42″	
Angle L. 7. to A. 6.	+ 27° 4′ 10″	
Azimuth A. 7. A. 6.	333° 50′ 52″	
Angle L. 7. to A. 8.	—144° 47′ 10″	
Azimuth A. 7. A. 8.	161° 59′ 32″	

Azimuth at Station A. 9.

	h. m. s.	
Mean Reading of Watch	4. 47. 18·75	
Approximate L. S. T.	13. 14. 00	
R. A. of Polaris	1. 25. 11	
Hour angle (arc)	— 2° 47′ 45″	
Azimuth of Polaris	— 4′ 02″	
Mean Circle on Polaris	0° 38′ 56″	
Meridian Reading	0° 42′ 58″	on N
„ „	180° 42′ 58″	on S
Mean Circle Reading on A. 8.	160° 00′ 16″	
Azimuth A. 9. A. 8.	339° 17′ 18″	

Azimuth at A. 9 *bis*.

	h. m. s.	
Reading of theodolite on A. 9.	320° 26′ 00″	
Meridional Reading	2° 7′ —	on S
Azimuth (A. 9. *bis*) A. 9.	318° 19′ 00″	

AZIMUTH AT STATION A. 10.

	h. m. s.	
Mean Reading of Watch	5. 41. 33·5	
Local Mean Time	8. 11. 58·5	
Sun's Meridian Passage	12. 02. 10·0	
Hour angle	3. 50. 11·5	
Log tan δ	$\bar{1}$· 636595	
Sun's azimuth	83° 18′ 15″	from N
„ „	265° 18′ 15″	from S
Mean Circle on Sun	265° 05′ 19″	
Meridian Reading	1° 47′ 04″	on S
Mean Circle Reading on A. 9. *bis*	328° 25′ 00″	
Azimuth A. 10. (A. 9. *bis*)	326° 37′ 56″	

AZIMUTH AT STATION A. 11.

	h. m. s.	
Mean Reading of Watch	4. 21. 58·0	
Approximate L. S. T.	13. 07. 56	
R. A. of Polaris	1. 25. 16	
Hour angle (time)	17. 20	
Declination	88° 48′ 01″	
Azimuth of Polaris	179° 53′ 40″	
Mean Circle on Polaris	182° 01′ 58″	
Meridian Reading	2° 08′ 18″	on S
Mean Circle Reading on A. 10. *bis*	338° 31′ 24″	
Azimuth A. 11. (A. 10. *bis*)	336° 23′ 06″	
Mean Circle Reading on A. 12.	192° 05′ 20″	
Azimuth A. 11. A. 12.	189° 57′ 02″	

AZIMUTH AT STATION A. 13.

	h. m. s.	
Mean Reading of Watch	4. 18. 26	
Approximate L. S. T.	13. 19. 57·5	
R. A. of Polaris	1. 25. 19·8	
Hour angle (time)	5. 22·3	
Declination	88° 48′ 01″·3	
Azimuth of Polaris	179° 58′ 03″	
Mean Circle on Polaris	181° 56′ 38″	
Meridian Reading	1° 59′ 35″	on S
Mean Circle Reading on C.*	117° 19′ 15″	
Azimuth A. 13. C.	115° 19′ 40″	

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* See diagram (p. 40)

Azimuth (A.13.) C.	115° 19′ 40″
„ C. (A.13.)	295° 19′ 40″
Angle (A. 13.) C F	25° 2′ 30″
Azimuth C. F.	320° 22′ 10″
„ F. C.	140° 22′ 10″
Angle C F E.	2° 26′ 5″
Azimuth F. E.	142° 48′ 15″
Angle E F (A.12.)	193° 27′ 20″
Azimuth F. (A.12.)	336° 15′ 35″

(b) *Latitude and local time.*—These are found in one computation in a great majority of cases. Only where the sun has been used instead of a star a different process is employed. Taking first the star observations we will use those at station A. 4. as a type.

The latitude assumed as most probable was 29° 41′ 30″ N. and the correction of the watch on local sidereal time at the epoch of the first pointing was 7 h. 33 m. 37 s. Adding this to the time of observation and adding further a, the acceleration, we have the sidereal time and then the hour angle. From this angle and the known declination we get the natural cosine of the star's zenith distance by the formula

$$\text{Cos}\ \zeta = \sin\varphi\sin\delta + \cos\varphi\cos\delta\cos t.$$

in which ζ is the zenith distance, φ the assumed latitude, δ the known declination, and t the hour angle on the given assumption as to the correction of the chronometer. To this cosine is to be added ·00005 for every division of the bubble, this being the value found by a series of direct observations on Polaris. Consider first the stars α Herculis and ο Leonis which are near the prime vertical and respectively east and west. The corrected natural sines are 0·47736 and 0·47712 differing by 240 units of the sixth decimal place. Owing to the proximity of both stars to the prime vertical, we ascribe this difference entirely to error of the watch to find which we proceed as follows. Half of 240 is 120, and this by Table XXVIII "Hints to Travellers" Vol. I Ed. 1901, is the proportional part for 28″ in a natural cosine of the order 0·477. A prime vertical star of small declination moves through this distance in approximately 2 seconds. It is clear then that if we were to recalculate with a clock correction 2 seconds smaller, the first star would come out at 28″ greater zenith distance and the second at 28″ less. The natural cosines would then be equal. The correction —2 seconds is therefore adopted, and we proceed to find the latitude. Strictly we ought to recalculate with the revised clock correction. but the modification amounting only to 2 seconds, we may continue

After correcting all natural cosines for the bubble readings we group all north stars together and take the mean of the natural cosines viz., 0·477387. The south stars are also made in two sub-groups S.E. and S.W. The mean of the former is 0·477265 and of the latter 0·477145.

The mean of these two means may be taken as free from clock error (if as in the present instance, such error is small) and it amounts to 0·477205. The difference between 0·477387 and 0·477205 is 182, half of which is 91. Referring again to Table XXVIII (loc. cit.) we find that the difference 91 corresponds to 21″. It is clear that if the work were recalculated with latitude diminished by 21″ the N. and S. groups would yield identical natural cosines. Accordingly—21″ is adopted as the correction to the latitude and the result is 20° 41′ 09″.

In order to use the rapid method above described some experience of this class of computation is necessary, and in particular the first approximations used should not be greatly in error, and the stars used should be distributed as symmetrically as possible. In selected cases my results have been recomputed after my return to Cairo, using the *final* values of latitude and time and the result has been entirely satisfactory. I would point out that I was working under considerable pressure to complete my computations in time for the requirements of the Commission and that the advantage accruing from a more elaborate computation would have been entirely inappreciable.

(c) *Local time by the sun's altitude.*—This was rarely employed. The method adopted is strictly that of "Hints to Travellers" Vol. I., Ed. 1901, so that it is not necessary to add any explanatory remarks.

NOTE.—At several stations the exact correction of the chronometer (on L. S. T. at the epoch of first observation) was originally computed, with a view to fixing chronometric longitude. As explained in the text no use has been made of chronometric longitudes, so that these exact corrections serve no purpose. Nevertheless when they have been obtained, they are exhibited in the following tables for the benefit of those who may be interested. At Stations Suez (astronomical) and A. 13. the corrections in question are required for longitude purposes. The longitude of Station A. 1. is deduced from solar observations only, (see pp. 26 and 27) and not from those in the following tables (p. 18). The observations at Station A. 4. are computed *in extenso* as an example.

1906, May 23.

LOCAL TIME AT SUEZ (Astronomical Station).

T = time by watch.

ΔT provisionally assumed 6 h. 24 m. 54 s. (on L. S. T. at epoch of the first observation).

Latitude assumed 29° 57′ N.

Star.	Polaris.	β Canis Minoris.	α Canis Min.	α Serpentis.
T	5. 00. 07·0	5. 02. 41·0	5. 07. 51·0	5. 12. 49·0
Cos ζ	0·48350	0·48400	0·48402	0·48222

Star.	β Herculis.
T	5. 28. 09·5
Cos ζ	0·48265

dt = 16·0 s.

h. m. s.

ΔT (final) = 6. 25. 10·0 (on L. S. T. at epoch of first observation)

= 2. 23. 31·7 Slow on L. M. T.

1906, May 24.

LOCAL TIME AT SUEZ (Astronomical Station).

ΔT provisionally assumed 6 h. 29 m. 10·0 s. (at epoch of first observation).
Latitude assumed 29° 56′ 30″ N.

Stars.	Polaris.	α Canis Min.	α Serpentis.
T	5. 00. 23·0	5. 03. 54·0	5. 08. 46·0
Cos ζ	0·48310	0·48304	0·48320

dt = − 1·5 s.

h. m. s.

ΔT (final) = 6. 29. 08·5 (on L. S. T. at epoch of first observation).

= 2. 23. 33·5 slow on L. M. T.

1906, May 30.

LATITUDE AT TABA, STATION A. 1.

ΔT provisionally assumed 7 h. 02 m. 07·0 s. (on L.S.T. at epoch of first observation). From the prime vertical stars Castor, δ Herculis, α Hydrae, is deduced the improved value 7 h. 02 m. 06·0 s. which is employed in the remaining stars.

Latitude assumed 29° 29′ N.

Stars.	Polaris.	Castor.	δ Herculis.	α Hydrae.
T	5. 00. 27·5	5. 19. 07·0	5. 28. 14·5	5. 43. 30·5
Cos ζ	0·47502	0·47493	0·47507	0·47511

Stars.	ε Corvi.	α Scorpii.	Polaris.
T	7. 23. 00·0	7. 31. 03·5	7. 43. 20·0
Cos ζ	0·47514	0·47514	0·47498

$d\varphi$ = + 16″

Final latitude 29° 29′ 16″ N.

[ΔT (final) 7 h. 02 m. 06 s.]

NOTE.—Station B. 1. is 3″·6 south of A. 1. and its latitude is therefore 29° 29′ 12″·4 N.

1906, May 3 .

LATITUDE OF AQABA CAMP. STATION A. 2.

ΔT provisionally assumed 7 h. 06 m. 26 s. for all stars.
Latitude assumed 29° 32′ N.

Stars.	Polaris.	Pollux.	ε Herculis.	Polaris.
T … … …	5. 15. 51·5	5. 19. 29·5	5. 23. 59·0	7. 17. 43·5
Cos ζ … … …	0· 47529	0· 47532	0· 47528	0· 47523

Stars.	α Scorpii	β Corvi
T … … …	7. 27. 19·5	7. 37. 24·0
Cos ζ … … …	0· 47519	0· 47519

$d\varphi$ = − 8″

Final latitude 27° 31′ 52″ N.

[ΔT (final) 7 h. 06 m. 26·5 s.]

1906, June 5.

LATITUDE OF RAS RADADI. STATION A. 3.

ΔT provisionally assumed 7 h. 25 m. 44·5 s. for the prime vertical stars α Herculis, *o* Leonis. From these I deduce the improved value 7 h. 25 m. 46·5 s. which is used for the remaining stars.
Latitude assumed 29° 38′ 30″ N.

Stars.	Polaris.	α Herculis.	β Scorpii	*o* Leonis.
T … … …	5. 17. 30·5	5. 23. 44·5	6. 00. 33·5	6. 22. 13·5
Cos ζ … … …	0· 47658	0· 47641	0· 47650	0· 47674
For level … …	0· 00000	+0· 00005	+0· 00004	−0· 00005
Corrected cos ζ …	0· 47658	0· 47646	0· 47654	0· 47669

Stars.	Polaris.	Polaris.	ε Corvi.	α Scorpii.
T … … …	6. 24. 28·5	6. 39. 20·5	6. 57. 45·0	7. 09. 53·0
Cos ζ … … …	0· 47639	0· 47656	0· 47658	0· 47660
For level … …	+0· 00018	0· 00000	+0· 00001	−0· 00001
Corrected cos ζ …	0· 47657	0· 47656	0· 47659	9· 47659

$d\varphi$ = + 1″

Final latitude 29° 38′ 31″ N.

[ΔT (final) 7 h. 25 m. 46·5 s.]

1906, June 7.

Latitude and Time at Bir Said. Station A. 4.

ΔT assumed 7 h. 33 m. 37 s. on L.S.T. at epoch of first observation. Latitude assumed 29° 41′ 30″ N.

STARS.	Polaris.	α Herculis.	β Scorpii.	o Leonis.	Polaris.	Polaris.	ε Corvi.	α Scorpii.	β Corvi.
	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.
Watch A...	5. 08. 33·5	5. 16. 06·5	5. 53. 19·5	6. 14. 12·0	6. 36. 57·0	6. 44. 21·5	6. 49. 19·0	7. 02. 58·0	7. 08. 17·0
ΔT	7. 33. 37·0	7. 33. 37·0	7. 33. 37·0	7. 33. 37·0	7. 33. 37·0	7. 33. 37·0	7. 33. 37·0	7. 33. 37·0	7. 33. 37·0
a	00·0	01·3	06·5	10·9	14·5	15·9	16·9	18·9	19·8
Sum...	12. 42. 10·5	12. 49. 44·8	13. 27. 03·0	18. 47. 59·9	14. 10. 48·5	14. 18. 14·4	14. 23. 12·9	14. 36. 53·9	14. 42. 13·8
A.R....	1. 24. 57·9	17. 10. 23·5	16. 00. 00·2	9. 36. 08·0	1. 24. 57·9	1. 24. 57·9	12. 05. 18·4	16. 23. 40·7	12. 29. 28·0
diff.	0. 42. 47·4	4. 20. 38·7	2. 32. 57·2	4. 11. 51·9	0. 45. 50·6	0. 53. 16·5	2. 17. 54·5	1. 46. 46·8	2. 12. 45·8
t (arc)	10° 41′ 50″	65° 09′ 40″	38° 14′ 18″	62° 57′ 59″	11° 27′ 39″0	13° 19′ 07″5	34° 28′ 38″	26° 41′ 42″	33° 11′ 27″
δ	88° 48′ 03″	14° 29′ 54″	−19° 32′ 54″	10° 19′ 08″	88° 48′ 03″	88° 48′ 03″	−22° 06′ 02″	−26° 13′ 24″	−22° 52′ 49″
level...	0	− 1· 40	+ 0· 35	+ 1· 10	+ 0· 50	+ 2· 6	− 0· 40	+ 0· 45	+ 0· 45
log sin φ	$\bar{1}$·694897	$\bar{1}$·694897	$\bar{1}$·694897	$\bar{1}$·694897	$\bar{1}$·694897	$\bar{1}$·694897	$\bar{1}$·694897	$\bar{1}$·694897	$\bar{1}$·694897
log sin δ	$\bar{1}$·999905	$\bar{1}$·388551	$\bar{1}$·524528	$\bar{1}$·253161	$\bar{1}$·999905	$\bar{1}$·999905	$\bar{1}$·575457	$\bar{1}$·645293	$\bar{1}$·589734
Sum...	$\bar{1}$·694802	$\bar{1}$·093448	$\bar{1}$·219425	$\bar{2}$·948058	$\bar{1}$·694802	$\bar{1}$·694802	$\bar{1}$·270354	$\bar{1}$·340190	$\bar{1}$·284631
Nat. No. (1)	0·49522	0·12401	−0·16574	0·08873	0·49522	0·49522	−0·18636	−0·21887	−0·19259
log cos φ...	$\bar{1}$·938860	$\bar{1}$·938860	$\bar{1}$·938860	$\bar{1}$·938860	$\bar{1}$·938860	$\bar{1}$·938860	$\bar{1}$·938860	$\bar{1}$·938860	$\bar{1}$·938860
log cos δ...	$\bar{2}$·320725	$\bar{1}$·985945	$\bar{1}$·974217	$\bar{1}$·992918	$\bar{2}$·320725	$\bar{2}$·320725	$\bar{1}$·966857	$\bar{1}$·952830	$\bar{1}$·964410
log cos *t*...	$\bar{1}$·992386	$\bar{1}$·623320	$\bar{1}$·895115	$\bar{1}$·657546	$\bar{1}$·991253	$\bar{1}$·988159	$\bar{1}$·916112	$\bar{1}$·951051	$\bar{1}$·922649
sum...	$\bar{2}$·251971	$\bar{1}$·548125	$\bar{1}$·808192	$\bar{1}$·589324	$\bar{2}$·250838	$\bar{2}$·247744	$\bar{1}$·821829	$\bar{1}$·842741	$\bar{1}$·825919
Nat. No. (2)	0·01786	0·35328	8·64297	0·38844	0·01782	0·01769	0·66348	0·69621	0·66976
* Nat. cos ζ	0·47736	0·47729	0·47723	0·47717	0·47740	0·47753	0·47712	0·47734	0·41717
For level	0	+7	−2	−5	−2	−13	+2	−2	−2
Corrected cos ζ	0·47736	0·47736	0·47721	0·47712	0·47738	0·47740	0·47714	0·47732	0·47715

* Nat. cos ζ = Nat. No. (1) + Nat. No. (2).

DISCUSSION OF LATITUDE OBSERVATIONS AT BIR SAID. STATION A. 4.

STARS.	N	S E	S W
Polaris	0·47736	......	......
β Scorpii...	......	0·47721	......
Polaris	0·47738	......	......
Polaris	0·47740	......	......
ι Corvi	......	......	0·47714
α Scorpii...	......	0·47732	......
β Corvi	......	......	0·47715
Means	0·477380	0·477265	0·477145
		0·477205	
$\frac{N-S}{2}$	+0·000088		
Equivalent	−21"		
Latitude assumed...	29°41′30"N		
Final Latitude	29°41′09"N		

DISCUSSION OF ΔT AT SAME STATION.

STARS.	E	W
α Herculis	0·47736	......
o Leonis	......	0·47712
$\frac{E-W}{2}$...	+0·000012	......
Equivalent	− 2 s.	......
ΔT (assumed)...	7 h. 33 m. 37 s.	on L.S.T. at epoch of first observation.
ΔT (final)...	7 h. 33 m. 35 s.	

1906, June 10.

LATITUDE OF ABU QERADI. STATION. A. 6.

ΔT provisionally assumed 7 h. 45 m. 27 s. for all Stars.
Latitude assumed 29° 54' N.

Stars.	Polaris.	α Ophiuchi.	β Scorpii.
T	5. 08. 06·0	5. 29. 16·0	5. 44. 03·5
Cos ζ	0· 48040	0· 48039	0· 48046
For level	0	+0· 00006	−0· 00006
Corrected cos ζ ...	0· 48040	0· 48045	0· 48040

Stars.	ο Leonis.	Polaris.	Polaris.
T	6. 01. 28·5	6. 08. 02·5	6. 12. 29·5
Cos ζ	0· 48030	0· 48038	0· 48042
For level	−0· 00004	+0· 00002	−0· 00001
Corrected cos ζ ...	0· 48026	0· 48040	0· 48041

Stars.	ε Corvi.	α Scorpii.
T	6. 34. 40·5	6. 55. 03·5
Cos ζ	0· 48018	0· 48036
For level	+0· 00011	+0· 00003
Corrected cos ζ ...	0· 48029	0· 48039

$d\varphi = \quad - 7''$

Final Latitude 29° 53' 53" N.

[ΔT (final) 7 h. 45 m. 25·5 s.]

1906, June 19.

LATITUDE OF STATION A.7. (near Thamelet el Swelma).

ΔT provisionally assumed 8 h. 19 m. 20·0 s. for the prime vertical stars 72 Ophiuchi and α Leonis. From these I deduce the improved value 8 h. 19 m. 32 s.

Latitude assumed 30° 07' 00" N.

Stars.	Polaris.	72 Ophiuchi.	Polaris.
T	5. 13. 08·5	5. 35. 14·5	5. 41. 26·5
Cos ζ	0· 48355	0· 48277	0· 48376
For level	0· 00000	0· 00004	−0· 00017
Corrected cos ζ ...	0· 48355	0· 48281	0· 48359

Stars.	Polaris.	ε Corvi.	α Leonis.
T	5. 45. 06·0	5. 57. 28·0	5. 58. 03·5
Cos ζ	0· 48380	0· 48372	0· 48440
For level	−0· 00020	−0· 00009	−0· 00009
Corrected cos ζ ...	0· 48360	0· 48363	0· 48431

Stars.	α Scorpii.
T	6. 25. 21·5
Cos ζ	0· 48356
For level	−0· 00006
Corrected cos ζ ...	0· 48350

$d\varphi = \quad - 2''$

Final Latitude 30° 06' 58" N.

[ΔT (final) 8 h. 19 m. 32 s.]

1906, June 17.

LATITUDE OF GEBEL SEMAWI. STATION A. 8.

ΔT provisionally assumed 8 h. 12 m. 18·5 s. for all stars.
Latitude assumed 30° 22′ 10″ N.

Stars.	Polaris.	β Scorpii.	o Leonis.
T	5. 17. 25·5	5. 23. 09·5	5. 32. 15·5
Cos ζ	0·48740	0·48752	0·48751
For level	0	−0·00003	−0·00006
Corrected cos ζ ...	0·48740	0·48749	0·48745

Stars.	72 Ophiuchi.	Polaris.	ε Corvi.
T	5. 43. 47·5	5. 50. 18·5	6. 01. 00·5
Cos ζ	0·48760	0·48764	0·48747
For level	0·00001	−0·00017	0·00000
Corrected cos ζ ...	0·48761	0·48747	0·48747

$d\varphi =$ + 4″

Final Latitude 30° 22′ 14″ N.

1906, June 21.

LATITUDE OF GEBEL KHARUF. STATION A. 9.

ΔT provisionally assumed 8 h. 26 m. 44 s. for all stars.
Latitude assumed 30° 20′ N.

Stars.	Polaris.	o Leonis.	Polaris.	72 Ophiuchi.
T	5. 04. 13·5	5. 17. 15·5	5. 18. 51·0	5. 30. 05·5
Cos ζ	0·48939	0·48923	0·48941	0·48956
For level ...	0·00000	−0·00006	0·00000	−0·00009
Corrected cos ζ	0·48939	0·48917	0·48941	0·48947

Stars.	Polaris.	ε Corvi.	α Scorpii.
T	5. 32. 32·0	5. 44. 40·5	6. 26. 16
Cos ζ	0·48959	5·48934	0·48925
For level ...	−0·00013	−0·00011	0·00000
Corrected cos ζ	0·48946	0·48923	0·48925

$d\varphi =$ − 21″

Final Latitude 30° 29′ 39″ N.

[ΔT (final) 8 h. 26 m. 41·5 s.]

1906, June 24d. 18h.

LOCAL TIME BY SUN'S ALTITUDE OBSERVED WITH THE THEODOLITE AT RAS EL AIN QUDERAT. STATION A. 10.

Latitude assumed 30° 41′ 20″ N.

	Time by Watch A.	True altitude ⊙.
Mean	5 h. 59 m. 07·8 s.	42° 32′ 07″

	h. m. s.
∴ Local Mean Time	8. 29. 32·1 (a. m.)
Watch A	5. 59. 07·8
Slow for L.M.T.	**2. 30. 24·3**

LATITUDE AT GEBEL UM HAWAWIT. STATION A. 11.

ΔT provisionally assumed 8 h. 45 m. 59 s. for all stars.
Latitude assumed 30° 51′ 32″ N.

Stars.	Polaris.	Polaris.	ε Corvi.
T	4. 50. 46·5	4. 57. 37·0	5. 19. 49·5
Cos ζ	0· 49486	0· 49490	0· 49481
For level	0	−0· 00003	0· 00001
Corrected cos ζ ...	0· 49486	0· 49487	0· 49482
Stars.	**α Leonis.**	**β Cygni.**	**α Scorpii.**
T	5. 28. 06·5	5. 59. 36·5	6. 15. 44·5
Cos ζ	0· 49478	0· 49504	0· 49499
For level	−0· 00003	−0· 00003	−0· 00003
Corrected cos ζ ...	0· 49475	0· 49501	0· 49496

$d\varphi$ + 5″

Final Latitude 30° 51′ 87″ N.

1906, June 27.

LATITUDE OF KHASHM EL QARN. STATION A. 12.

ΔT assumed provisionally 8 h. 49 m. 53 s. for all stars.
Latitude assumed 30° 58′ 00″ N.

Stars.	Polaris.	Polaris.	Polaris.	ε Corvi.
T	4. 46. 50·0	4. 50. 40·5	5. 00. 30·5	5. 14. 11·5
Cos ζ	0· 49650	0· 49652	0· 49658	0· 49644
For level ...	0· 00000	−0· 00005	−0· 00007	−0· 00010
Corrected cos ζ	0· 49650	0· 49647	0· 49651	0· 49634
Stars.	**α Leonis.**	**β Cygni.**	**β Cygni.**	**α Scorpii.**
T	5. 23. 42·5	5. 32. 09·5	5. 56. 01·5	6. 14. 22·0
Cos ζ	0· 49631	0· 49633	0· 49649	0· 49639
For level ...	−0· 00001	−0· 00002	−0· 00001	−0· 00001
Corrected cos ζ	0· 49630	0· 49631	0· 49648	8· 49639

$d\varphi$ = − 18″

Final Latitude 30° 57′ 42″ N.

LATITUDE AND TIME AT RAFA. STATION A. 13.

ΔT provisionally assumed 9 h. 00 m. 55·0 s. for all stars.
Latitude assumed 31° 17′ 30″ N.

Stars.	Polaris.	Polaris.	α Leonis.	Polaris.
T	4. 55. 03·5	4. 57. 52·5	5. 10. 59·5	5. 14. 04·5
Cos ζ	0· 50155	0· 50158	0· 50165	0· 50181
For level ...	0	−0· 00003	−0· 00004	−0· 00025
Corrected cos ζ	0· 50155	0· 50155	0· 50161	0· 50156
Stars.	γ Aquilae.	α Aquilae.	τ Scorpii.	β Leonis.
T	6. 36. 48·5	6. 45. 27·5	6. 54. 07·5	6. 57. 33·5
Cos ζ	0· 50172	0· 50173	0· 50172	0· 50168
For level ...	−0· 00006	−0· 00008	−0· 00003	−0· 00008
Corrected cos ζ	0· 50166	0· 50165	0· 50169	0· 50160
Stars.	γ Virginis.	ξ Cygni.	α Ursae Maj.	τ Scorpii.
T	7. 08. 59·5	7. 24. 16·0	7. 32. 22·5	8. 03. 19·5
Cos ζ	0· 50166	0· 50168	0· 50162	0· 50173
For level ...	−0· 00006	−0· 00008	−0· 00008	−0· 00005
Corrected cos ζ	0· 50158	0· 50160	0· 50154	0· 50168

dt = −0·4 s.

ΔT (final) = 9. 00. 54·6 (h. m. s.) on L. S. T. at epoch of first observation.
= 2. 29. 28·3 slow on L. M. T.
dφ = + 16″
Final Latitude 31° 17′ 46″ N.

1906, May, 23d. 2 h.

LOCAL TIME AT SUEZ (Astronomical Station) by Sextant altitudes of the Sun.

Times by Watch. A.	h. m. s.	Observed Double Altitudes.		
1st limb	1. 57. 37	59° 53′ 10″	Mean	58° 07′ 27″
2nd limb	2. 00. 05		index	− 01′ 25″
			2)	58° 06′ 02″
1st limb	2. 01. 05	58° 24′ 40″	altitude	29° 03′ 01″
2nd limb	2. 03. 30		parallax	+ 07″
1st limb	2. 06. 30	56° 04′ 30″	refraction	−1′ 45″
2nd limb	2. 08. 57			
Mean	2. 02. 57	58° 07′ 27″	True altit.	29° 01′ 23″

Latitude	29° 57′ 00″
N. P. D.	69° 31′ 36″
Equation of Time	3 m. 32·0 s.
	h. m. s.
Hour angle found	4. 30. 01·7
	−3. 32·0
Local Mean Time	4. 26. 29·7
Watch A	2. 02. 57·0
Slow for L.M.T.	2. 23. 32·7

1906, May, 24 d. 1 h. 30 m.

LOCAL MEAN TIME AT SUEZ (Astronomical Station)
by Sextant altitudes of the Sun.

Times by Watch A.	h. m. s.	Observed Double Altitudes.		
1st limb	1. 15. 16·5	78° 18′ 00″	Mean	77° 38′ 00″
2nd limb	1. 17. 41·0		index	−1′ 50″
			2)	77° 36′ 10″
				38° 48′ 05″
1st limb	1. 18. 20·0	76° 58′ 00″	parallax	+ 00′ 07″
2nd limb	1. 20. 46·0		refraction	− 01′ 15″
Mean	1. 18. 00·8	77° 38′ 00″		38° 46′ 57″

Latitude … … … … … … … … …	29° 57′ 00″
N. P. D. … … … … … … … … …	69° 20′ 28″
Equation of Time … … … … … … …	3 m. 28 s.
	h. m. s.
Hour angle found … … … … … … …	3. 45. 04·1
Equation of Time … … … … … … …	− 3. 28·0
Local Mean Time … … … … … … …	3. 41. 36.1
Watch A. … … … … … … … … …	1. 18. 00·8
Slow for L.M.T. … … … … … … …	2. 23. 35·3

1906, May, 26 d. 19 h.

LOCAL MEAN TIME AT TABA. STATION A. 1.
by Sextant altitudes of the Sun.

Times by Watch A.	h. m. s.	Observed Double Altitudes.		
1st limb	6. 35. 06·0	105° 58′ 00″	Mean	106° 25′ 25″·5
2nd limb	6. 37. 34·5			− 1′ 22″·5
			2)	106° 24′ 30″·0
1st limb	6. 41. 31·5	105° 44′ 50″		53° 12′ 15″·0
2nd limb	6. 43. 56·0			
1st limb	6. 45. 53·0	107° 38′ 00″	parallax	+ 5″·4
2nd limb	6. 48. 17·0		refraction	− 44″·0
1st limb	6. 49. 55·0	109° 22′ 40″		53° 11′ 36″·4
2nd limb	6. 52. 19·0			
Mean	6. 44. 19·0	106° 25′ 52″·5		

Latitude … … … … … … … …		29° 29′
N. P. D. … … … … … … … …		68° 51′ 00″
		h. m. s.
Hour angle found … … … … … …		− 2. 39. 29·5
Equation of Time … … … … … …		− 3. 11·1
	h.	h. m. s.
Local Mean Time … … … … … …	24	− 2. 42. 40·6
or … … … … … … …		21. 17. 19·4
Watch A … … … … … … … …		18. 44. 19·4
Slow for L.M.T. … … … … … …		2. 33. 00·4

1906, May, 27d. 1h.

LOCAL MEAN TIME AT TABA. STATION A. 1.
by Sextant altitudes of the Sun.

Times by Watch A.	h. m. s.	Observed Double Altitudes.		
1st limb	12. 47. 49	86° 34′ 30″	Mean	84° 04′ 12″·5
2nd limb	12. 50. 15		index	− 1′ 22″·5
			2)	84° 02′ 50″·0
1st limb	12. 51. 31	84° 58′ 50″		42° 01′ 25″·0
2nd limb	12. 53. 56			
1st limb	12. 55. 44	83° 08′ 00″	parallax	+ 6·5
2nd limb	12. 58. 09		refraction	− 64·8
1st limb	12. 59. 16·5	81° 35′ 30″		42° 00′ 26″·7
2nd limb	13. 01. 40·5			
Mean	12. 54. 47·6	84° 04′ 12″·5		

Latitude	29° 29′
N. P. D.	68° 48′ 13″
	h. m. s.
Hour angle found	3. 30. 59·7
Equation of Time	− 3. 09·8
Local Mean Time	3. 27. 49·9
Watch A.	12. 54. 47·6
Slow for L. M. T.	2. 33. 02·3

1906, June, 9d. 10h.

LOCAL TIME AT STATION A. 5.
by altitudes of the Sun observed with theodolite.

Mean of Times by Watch A.	Mean of Observed Altitudes.
12 h. 03 m. 19 s.	54° 15′ 52″
	+ 7″
	− 42″

True Alt. of Sun's centre	54° 15′ 17″
Latitude	29° 46′
N. P. D.	67° 07′
	h. m. s.
Hour angle found	2. 37. 22
Equation of Time	− 1. 11
Local Mean Time	2. 36. 11
Watch A.	12. 03. 19
Slow for L. M. T.	2. 32. 52

1906, June, 24 d. 18 h.

LOCAL TIME AT STATION A. 10.

by altitudes of the Sun observed with theodolite a. m.

Mean of Times by Watch A.	Mean of Observed Altitudes.
h. m. s.	
5. 59. 07·8	42° 33′ 05″
12.	+ 07″
17. 59. 07·8	− 1′ 05″
True Alt. Sun's centre	42° 32′ 07″

Latitude	30° 39′ 03″
Altitude	42° 32′ 07″
N. P. D.	66° 34′ 46″
	h. m. s.
Hour angle found	3. 32. 36·4
Apparent Time...	20. 27. 23·6
Equation Time...	+ 2. 08·5
Local Mean Time	20. 29. 32·1
Watch A....	17. 59. 07·8
Slow for L.M.T....	2. 30. 24·3

(d) *Latitude by the sun's altitude near the meridian.*—This method is not favourable for the computer in summer in low latitudes. It was therefore used once only, *viz.* at Station A.10. The special circumstance which obliged me to resort to this method has been stated in the general narrative. None of the standard works give rules for reducing extra meridian observation when the object is near the zenith, and the ordinary formulae fail completely. Turning to the example in question I assumed latitude 30° 39′ 30″ and chronometer slow 2 h. 30 m. 25 s. on local mean time, and thence calculated the sun's hour angle, taking the time of meridian passage as at 0 h. 02 m. 10·1 s. I then calculated the zenith distance at each of the ten times of pointing. These zenith distances are written down under the column "Calculated." I have confronted these entries with the observed zenith distance corrected for semidiameter refraction, parallax, and also for R—L the assumed correction to be applied with signs + or − according as readings are face right or face left. The differences between "calculated" and "observed" must, near the meridian, obey the equation

$$\text{diff} = d\varphi \pm d\,z + \text{A}.\,t.\,dt$$

in which $d\varphi$ is the correction to the provisionally assumed latitude, $d\,z$ the same for the quantity R—L, t the hour angle assumed, dt its correction and A a constant quantity. The solution may be obtained graphically.

A preliminary examination gave me for the supplementary correction to R—L, 1′ 01″·6, and then I found for $d\varphi$, −27″. The latitude adopted is accordingly 30° 39′ 03″. The example just quoted is a second approximation; in my first I started with 30° 41′ 20″ and found $d\varphi = -2' \, 02''$.

The computation is tedious and only to be recommended in special cases.

1906, June, 24 d. 21 h.

LATITUDE BY THE SUN AT STATION A. 10.

Assumed latitude ... ... 30° 39' 30" N.
ΔT ... ... 2 h. 30 m. 25 s. on L.M.T.

	I.	II.	III.	IV.	V.
	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.
T	9. 14. 03·5	9. 19. 47·5	9. 26. 01·5	9. 32. 51·5	9. 37. 20
ΔT	2. 30. 25·0	2. 30. 25·0	2. 30. 25·0	2. 30. 25·0	2. 30. 25
Sum	11. 44. 28·5	11. 50. 12·5	11. 56. 26·5	12. 03. 16·5	12. 07. 45
⊙ Transit ...	12. 02. 10·0	12. 02. 10·0	12. 02. 10·0	12. 02. 10·0	12. 02. 10·0
Hour angle	− 17. 41·5	− 11. 57·5	− 5. 43·5	+ 1. 06·5	+ 5. 35
$90-\zeta$ (calc)...	81° 45' 31"	82° 17' 00"	82° 38' 52"	82° 45' 21"	82° 39' 13"

	VI.	VII.	VIII.	IX.	X.
	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.
T	9. 40. 40·5	9. 44. 30·5	9. 49. 59·5	9. 53. 27·5	9. 57. 27·5
ΔT	2. 30. 25	2. 30. 25	2. 30. 25	2. 30. 25	2. 30. 25
Sum	12. 11. 05·5	12. 14. 55·5	12. 20. 24·5	12. 23. 52·5	12. 27. 52·5
⊙ Transit ...	12. 02. 10·0	12. 02. 10·0	12. 02. 10·0	12. 02. 10·0	12. 02. 10·0
Hour angle	+ 8. 55·5	+ 12. 45·5	+ 18. 14·5	+ 21. 42·5	+ 25. 42·5
$90-\zeta$ (calc)...	82° 29' 31"	82° 13' 20"	81° 42' 03"	81° 17' 54"	80° 46' 32"

		Difference.	
Calculated altitudes.	Observed altitudes.	F.R.	F.L.
81° 45' 31"	81° 46' 59"	−1' 28"	...
82° 17' 00"	82° 18' 31"	−1' 31"	...
82° 38' 52"	82° 37' 59"	...	+0' 53"
82° 45' 21"	82° 44' 26"	...	+0' 55"
82° 39' 13"	82° 38' 59"	...	+0' 14"
82° 29' 31"	82° 30' 49"	−1' 18"	...
82° 13' 30"	82° 15' 21"	−2' 01"	...
81° 42' 03"	81° 43' 49"	−1' 46"	...
81° 17' 54"	81° 17' 56"	...	−0' 02"
80° 46' 32"	80° 46' 24"	...	+0' 08"
		−1' 36"·8	+0' 26"·4

deduced *dz* (F.R.) = −1' 01"·6
dz (F.L.) = −1' 01"·6

On applying correction ± *dz* to second column we have:—

Calculated minus observed.

−16"
−29"
−09"
−07"
−48"
−16"
−59"
−44"
−64"
−54"

and plotting these against the hour angle as described in the text we find when the hour angle is zero.

$$d\varphi = -27''$$

Final Latitude = 30° 29' 03" N.

(e) *Comparison of Chronometers*:—The Chronometers used are denoted:—

A	Usher and Cole		No. 31,111
B	„	„	28,608
C	„	„	28,756
D	„	„	30,520
E	„	„	30,811

The last named was rated to keep sidereal time. All the chronometers were compared together as frequently as time permitted from the beginning to the end of the expedition, but as no conclusions have been based on longitude by transport of chronometers on land, I do not include details of comparisons other than those required to establish the longitude of Taba by sea from Suez.

From information received at Helwan Observatory, the state of these chronometers was as follows:—

			h.	m.	s.		s.	
May 23, 1906.—	A	slow	2.	13.	41·00	losing	3·25	daily.
	B	„	0.	0.	31·00	„	1·20	„
	C	fast	0.	4.	24·15	gaining	3·15	„
	D	„	0.	1.	44·70	„	1·30	„
	E	„	0.	3.	27·90	„	4·60	„

The first four are by comparison with the standard time of Egypt which is by convention precisely 2 hours fast on Greenwich Observatory. The fifth is reckoned on local sidereal time of Helwan Observatory.* Below follow the various comparisons which were used in the computations of the longitude of Taba.

1906, May, 23 d. 3 h.

COMPARISON OF WATCHES AT SUEZ (Astronomical Station).

Title of Watch.	Time shewn.	Certified correction on G. M. T.	∴ Watch A slow on G. M. T.	Assuming as standard.
	h. m. s.	h. m. s.	m. s.	
A...	...	+0. 13. 41·0	13. 41·0	A
A...	...	...	...	
B...	5. 48. 10	−2.+00. 31·0	13. 15·0	B
A...	3. 35. 26	...	...	
C...	5. 52. 30	−2. 04. 24·2	13. 05·8	C
A...	3. 35. 00	...	...	
D...	5. 49. 40	−2. 01. 44·7	13. 17·3	D
A...	3. 34. 38	...	...	
E...	9. 48. 20	−6. 10. 09·4	12. 57·6	E
A...	3. 25. 13	...	...	

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* Longitude 2 h. 5 m. 22·1 s. E. of Greenwich, depending on the value for the transit station on the Moqattam Hill near Cairo, occupied by the Expedition to observe the Transit of Venus in 1874.

1906, May, 24 d. 5 h.

Comparison of watches at Suez (Astronomical Station).

Title of Watch.	Time shewn.	Certified correction on G. M. T.	∴ Watch A slow on G. M. T.	Assuming as standard.
	h. m. s.	h. m. s.	m. s.	
A...	...	+0. 13. 44·25	13. 44·25	A
A...	...	...	...	
B...	7. 26. 44	−2.+00. 32·20	13. 16·20	B
A...	5. 14. 00	...	...	
C...	7. 31. 54	−2. 04. 27·20	13. 11·80	C
A...	5. 14. 15	...	...	
D...	7. 29. 41·5	−2. 01. 46·00	13. 25·50	D
A...	5. 14. 30·0	...	...	
E...	11. 42. 10·5	−6. 14. 30·50	12. 55·00	E
A...	5. 14. 45·0	...	...	

1906, May, 25d. 19h.

Comparison at sea H. H. S. Nur el Bahr, 7 hours out of Suez.

Title of Watch.	Time shewn.	Certified correction on G. M. T.	∴ Watch A slow on G. M. T.	Assuming as standard.
	h. m. s.	h. m. s.	m. s.	
A...	...	+0. 13. 49·0	13. 49·0	A
A...	...	...	...	
B...	9. 29. 42·4	−2.+00. 34·0	13. 16·4	B
A...	7. 17. 00·0	...	...	
C...	9. 35. 03·0	−2. 04. 31·8	13. 16·2	C
A...	7. 17. 15·0	...	...	
D...	9. 32. 48·5	−2. 01. 45·0	13. 30·5	D
A...	7. 17. 30·0	...	...	
E...	13. 51. 32·0	−6. 20. 50·7	12. 56·3	E
A...	7. 17. 45·0	...	...	

1906, May, 26 d. 17 h.

COMPARISON OF WATCHES AT TABA, STATION A. 1.

Title of Watch.	Time shewn.	Certified correction on G. M. T.	∴ Watch A slow on G. M. T.	Assuming as standard.
	h. m. s.	h. m. s.	m. s.	
A...	...	+0. 13. 52·38	13. 52·38	A
A...	...	...	...	
B...	7. 33. 41·5	−2.+00. 35·20	13. 15·70	B
A...	5. 21. 00·0	...	...	
C...	7. 39. 07·0	−2. 04. 34·52	13. 17·80	C
A...	5. 21. 15·0	...	...	
D...	7. 36. 49·0	−2. 01. 49·25	13. 29·75	D
A...	5. 21. 30·0	...	...	
E...	11. 59. 13·0	−6. 24. 33·7	12. 54·30	E
A...	5. 21. 45·0	...	...	

1906, May, 27 d. 4 h.

COMPARISON OF WATCHES AT TABA, STATION A. 1.

Title of Watch.	Time shewn.	Certified correction on G. M. T.	∴ Watch A slow on G. M. T.	Assuming as standard.
	h. m. s.	h. m. s.	m. s.	
A...	...	+0. 13. 54·00	13. 54·00	A
A...	...	...	...	
B...	5. 39. 10·5	−2.+00. 35·80	13. 16·3	B
A...	3. 26. 30·0	...	...	
C...	5. 44. 36·0	−2. 04. 36·35	13. 14·7	C
A...	3. 26. 45·0	...	...	
D...	5. 42. 18·5	−2. 01. 49·90	13. 28·6	D
A...	3. 27. 00·0	...	...	
E...	10. 06. 22·0	−6. 26. 16·30	12. 50·7	E
A...	3. 27. 15·0	...	...	

(f) *Chronometric longitude.*—The greater number of longitudes referred to in this report are purely differential, being obtained by the method of latitude and azimuth. In two cases however the longitude has been deduced as the difference of local time between the observing station and a standard station. In the first of these, A. 1., the difference was found by the transport of chronometers from Suez to Taba. In the second A. 13 by exchange of telegraphic signals from Helwan Observatory to Rafa.

The observations for local time at Suez and at Taba will be found on pp. 18, 25, 26, 27. The observations watch A was at once compared with the others B. C. D. E. The section "comparison of chronometers" gives the method of reducing these comparisons. The longitude of A. 1. east of Suez is now found by the following computations. First we obtain the nominal chronometric longitude of Suez astronomical Station, east of Greenwich.

Suez. May 23, 1906.	Standard for G. M. T.				
	Watch A.	Watch B.	Watch C.	Watch D.	Watch E.
	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.
Watch A slow on L.M.T....	2. 23. 32·7	2. 23. 32·7	2. 23. 32·7	2. 23. 32·7	2. 23. 32·7
Watch A slow on G.M.T....	13. 41·0	13. 15·0	13. 05·8	13. 17·3	12. 57·6
Longitude E of Greenwich	2. 09. 51·7	2. 10. 17·7	2. 10. 26·9	2. 10. 15·4	2. 10. 35·1

The numbers in the upper row are taken from the computations for Suez, May 23, 1906 (p. 25). The last line gives the observed longitude of Suez from the solar observations of May 23.

Suez. May 23, 1906.	Standard for G. M. T.				
	A.	B.	C.	D.	E.
	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.
Watch A slow on L.M.T....	2. 23. 31·7	2. 23. 31·7	2. 23. 31·7	2. 23. 31·7	2. 23. 31·7
Watch A slow on G.M.T....	13. 41·0	13. 15·0	13. 05·8	13. 17·3	12. 57·6
Longitude E of Greenwich	2. 09. 50·7	2. 10. 16·7	2. 10. 25·9	2. 10. 14·4	2. 10. 34·3

This table is obtained in just the same way, the first line being taken from the computation of local time at Suez by star observation of May 23, 1906 (p. 18).

SUEZ. May 24, 1906.	STANDARD FOR G. M. T.				
	A.	B.	C.	D.	E.
	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.
Watch A slow on L.M.T.	2. 23. 35·3	2. 23. 35·3	2. 23. 35·3	2. 23. 35·3	2. 23. 35·3
Watch A slow on G.M.T.	13. 44·3	13. 16·2	13. 11·8	13. 25·5	12. 55·0
Longitude E	2. 09. 51·0	2. 10. 19·1	2. 10. 23·5	2. 10. 09·8	2. 10. 40·3

The above table has the same interpretation as the last, the date being however the 24th and the observation for time a solar one (p. 26).

SUEZ. May 24, 1906.	STANDARD FOR G. M. T.				
	A.	B.	C.	D.	E.
	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.
Watch A slow on L.M.T.	2. 23. 33·5	2. 23. 33·5	2. 23. 33·5	2. 23. 33·5	2. 23. 33,5
Watch A slow on G.M.T.	13. 44·3	13. 16·2	13. 11·8	13. 25·5	12. 55·0
Longitude E	2. 9. 49.2	2. 10. 17·3	2. 10. 21·7	2. 10. 8·0	2. 10. 38·5

This table is similar to the previous ones, date 24th, observation for time by star pointings (p. 18).

We find in the mean, using star observations only, longitude of Suez observation Station:—

	h. m. s.	
by Watch A as standard	2. 09. 49·9	Mean. 2.h. 10.m. 15·67s.
„ B „	2. 10. 17·0	
„ C „	2. 10. 23·8	
„ D „	2. 10. 11·2	
„ E „	2. 10. 36·4	

We need not be discouraged at the differences in these quantities as they are entirely due to the disturbance in the train journey. If we treat the results at Taba in exactly the same way, we shall find that the *difference of longitude* from Suez to Taba has fairly the same value whether we use watch A, B, C, D, or E as standard. As the longitude of Suez is already well known, it is only necessary to add to it the mean difference longitude thus found from the five chronometers.

LONGITUDE OF TABA. STATION A. 1.

1906, May 26, 19 h.	STANDARD FOR G.M.T.				
	A.	B.	C.	D.	E.
	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.
Watch A slow on L.M.T....	2. 33. 00·4	2. 33. 00·4	2. 33. 00·4	2. 33. 00·4	2. 33. 00·4
Watch A slow on G.M.T....	13. 52·4	13. 15·7	13. 17·8	13. 29·8	12. 54·3
Longitude E of Greenwich	2. 19. 08·0	2. 19. 44·7	2. 19. 42·6	2. 19. 30·6	2. 20. 06·1

The numbers in the first line are taken from the computation for time by the sun's altitude a.m. May 26, 19 h. (p. 26), those in the second from the comparison of chronometers on p. 32. Those in the last line are only to be used for finding the difference of longitude Taba—Suez, and no attention is to be given to them as absolute values.

LONGITUDE OF TABA. STATION A. 1.

1906, May 27, 1 h.	STANDARD FOR G.M.T.				
	A.	B.	C.	D.	E.
	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.
Watch A slow on L.M.T....	2. 33. 02·3	2. 33. 02·3	2. 33. 02·3	2. 33. 02·3	2. 33. 02·3
Watch A slow on G.M.T....	13. 54·0	13. 16·3	13. 14·7	13. 28·6	12. 50·7
Longitude E	2. 19. 08·3	2. 19. 46·0	2. 19. 47·6	2. 19. 33·7	2. 20. 11·6

The explanation of this Table is the same as of the previous one, but for the computation for time see, Taba, May 27, 1 h. (p. 27).

From the mean of the a.m. and p.m. determinations at Taba we get:—

	h. m. s.		
Taba E of Greenwich	2. 19. 08·15	by watch A	as standard.
	45·35	„ B	„
	45·10	„ C	„
	32·15	„ D	„
	68·85	„ E	„

Comparing these with the values found at Suez (p. 34) we have:—

	m. s.		
Taba E of Suez	9. 18·25	by A	as standard.
	9. 28·35	„ B	„
	9. 21·30	„ C	„
	9. 20·95	„ D	„
	9. 32·45	„ E	„
Mean	9. 24·26		

These results are as concordant as can be expected from the transport of chronometers and the probable error is about ± 1·5 sec. that is considerably less than half a mile.

The position of my station at Suez, by scaling off from the Admiralty chart, is found to be 2 h. 10 m. 14·5 s. and if to this we apply the difference just found, we get:—

	h.	m.	s.
Astronomical Station Suez ...	2.	10.	14·50 E
Taba (A. 1.) further		9.	24·26
Taba (A. 1.) E of Greenwich ...	2.	19.	38·76
or	34°	54′	42″ E

(g) *Longitude by telegraph.*—This method was used at Rafa and its computation presents no difficulty, given the corrections to the timekeepers at Helwan and at Rafa. In the following table are shown the times of sending and receiving groups of signals. Each entry is the mean of five concordant values. In other respects the computation speaks for itself. The correction of the watch A is taken from the Section on the determination of local times (p. 25), and the Greenwich mean times of sending and receiving at Helwan are communicated by the Observatory.

LONGITUDE OF RAFA. STATION A. 13.

by telegraphic signals from Helwan Observatory.

	1st. Group.	2nd. Group.	3rd. Group.
	h. m. s.	h. m. s.	h. m. s.
Received at Rafa	5. 55. 29·13	6. 04. 29·11	6. 12. 29·04
Sent from Helwan	6. 08. 01·00	6. 17. 01·00	6. 25. 00·90
Watch A slow on G. M. T. ...	0. 12. 31·87	0. 12. 31·89	0. 12. 31·86
Sent from Rafa	6. 00. 25·00	6. 08. 25·00	6. 16. 25·00
Received at Helwan	6. 12. 56·80	6. 20. 56·80	6. 28. 56·70
Watch A slow on G. M. T. ...	0. 12. 31·80	0. 12. 31·80	0. 12. 31·70

	h.	m.	s.
Watch A slow on G. M. T.	0.	12.	31·82
Watch A slow on L. M. T.	2.	29.	28·30
Longitude of Rafa	2.	16.	56·48
	34°	14′	07″·2 E

NOTE.—The quantities opposite "Received at Rafa" "Sent from Rafa" are those shewn by watch A uncorrected. Those opposite "Sent from Helwan" "Received at Helwan" are stated as Greenwich Mean Times. These are subject to small corrections, on full discussion, as are those opposite "Watch A slow on L. M. T." See discussion by Mr. Craig, p. 80 *et seqq.*

(h) *Triangulation* was little resorted to. At A. 9. (see diagram p. 39) it became necessary to know the distance to A. 9. *bis* in order to compute the difference of co-ordinates. A short base was measured at A. 9. *bis*, and the angles at the base were read with the theodolite. The distance A. 9. *bis* to A. 9. is then found by the rule $B = 180^\circ - (A + C)$ and

$$\frac{b}{\sin B} = \frac{a}{\sin A}$$

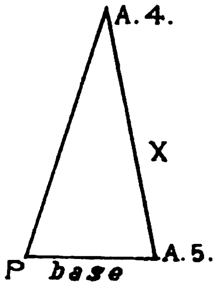
A more elaborate triangulation was made at Rafa, to bridge over some troublesome ground between A. 13. and A. 12. (See diagram p. 40). The length of the side (A. 13.) C was first found just as in the last example using (A. 13.) B as base and similarly the triangle C D (A. 13.) was completely solved using D E as base and the triangle D E F with the same base. In the triangle F E C two sides are known viz. F E, E C from the foregoing computations and the included angle F E C. Thus the length F C was found by the ordinary formula.

The azimuth of (A. 13.) C was observed in the ordinary course (see p. 15) and the angle B C (A. 13.) was observed, thus the azimuth F C was known. At F the angle C F (A. 12.) was observed so that the azimuth of F (A. 12.) was known. The present section deals only with the computation of the lengths (A. 13.) C and C F. In the section on co-ordinates (p. 43 *et seqq.*) these lengths are used in conjunction with their azimuths to compute the astronomical chain from A. 12. to A. 13.

The azimuths of F C and F (A. 12.) are found from that of (A. 13.) C (see p. 16).

TRIANGULATION AT A. 5.

(Communicated by Mr. KEELING: see p. 76).



Base-line A. 5. to P.

1st measurement = 365 metres.

2nd „ = 367 „

Mean = 366 „

Angle at A. 5. $54^\circ\ 12'$

„ P. $123^\circ\ 37'\frac{1}{4}$

∴ „ A. 4. $2^\circ\ 10'\frac{3}{4}$

$$x = 366\ \frac{\sin\ 123^\circ\ 37'\frac{1}{4}}{\sin\ 2^\circ\ 10'\frac{3}{4}}$$

$$= 366 \times \frac{0{\cdot}8327}{0{\cdot}0380}$$

$$= 8{\cdot}02 \text{ kms}^{*}.$$

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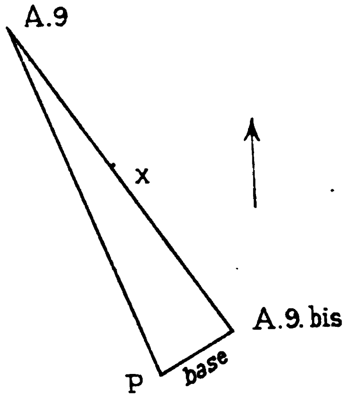
[*] Rounded off to 8·05 kms.

TRIANGULATION AT A. 9.

Base = 429 metres.



Angle at A. 9. *bis*	106° 47′ 35″
„ P.	68° 35′ 50″
∴ „ A. 9.	4° 36′ 35″
	180° 0′ 00″

log 429	2· 632457
log cosec A. 9.	1· 095407
log sin P.	$\bar{1}$· 969444
log x	3· 697308
x =	4982 metres.

Triangulation at Rafa.

Observations by Mr. Keeling.

Base A. 13. to B 218 m.

Base D to E 1049 m.

C A B ... ... 112° 20'·2

A B C ... ... 62° 52'·1

B C A ... ... 4° 47'·6

C D E ... ... 52° 46'·1

D E C ... ... 115° 6'·1

E C D ... ... 12° 7'·8

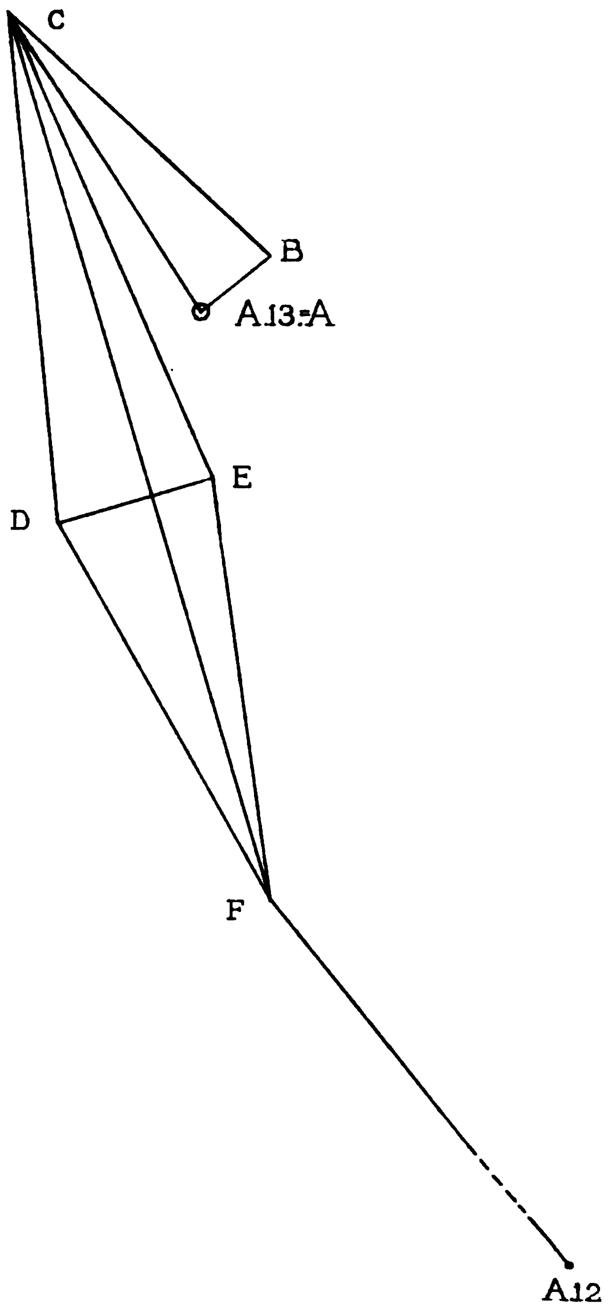
F D E ... ... 109° 7'·9

D E F ... ... 60° 6'·7

D F E ... ... 10° 45'·2

A C F ... ... 25° 02'·2

E F (A. 12.) ... 193° 27'·3



TRIANGULATION AT RAFA.

log sin A	$\bar{1}$· 966 1365	log A B	2· 338 4565
B	$\bar{1}$· 949 3645		
C	$\bar{2}$· 922 6105		
∴ log B C	3· 381 9825;	log A C	3· 365 2105
	m.		m.
B C	240 9·81	A C	2318·52
log sin E	$\bar{1}$· 956 9215	log E D	3· 020 7755
C	$\bar{1}$· 322 6066		
D	$\bar{1}$· 901 0102		
∴ log C D	3· 655 0904;	log E C	3· 599 1791
	m.		m.
C D	451 9·50	E C	3973·55
log sin F	$\bar{1}$· 270 7348	log E D	3· 020 7755
D	$\bar{1}$· 975 3208		
E	$\bar{1}$· 938 0400		
∴ log F D	3· 688 0807;	log F E	3· 725 3615

In the triangle F C E:—

log *o*	3· 725 3615	E = 60° 6′·7 + 115° 6′·0
log *f*	3· 599 1791	= 175° 13′
log tan φ	0· 126 1824	
φ	45° 49′ 50″	
45°—φ	0° 49′ 50″	
log tan (45°—φ)	$\bar{2}$· 161 2765	
log cot ½ E	$\bar{2}$· 622 3427	
log tan ½(F—C)	$\bar{4}$· 783 6192	
½(F—C)	2′ 05″	F = 2° 26′ 05″
½(F+C)	2° 24′ 00″	C = 2° 21′ 55″
log F C	3· 892 0864	

(i) *Co-ordinates. Computation of the traverse from Taba to Rafa.*— The preceding sections have shewn the method of computing the latitudes of astronomical stations, and the azimuths of the connecting lines. Given the longitude of Station B. 1., that of A. 2. can be calculated as follows:—

$$\text{diff. longitude} = \frac{\text{diff. latitude} \times L \times \tan A}{.T}$$

in which L and T are the factors for converting seconds of latitude and longitude into metres. They depend on the latitude of the station and can be found in geodetic tables; A is the azimuth of the connecting line. This is the formula actually used in the field as time did not permit of the rigorous spherical solution. On my return to Cairo, the traverse was recomputed rigorously and the differences noted are insensible on the scale of the map. In the calculations which follow the longitude of B. 1. was arbitrarily assumed as 34° 54′ 00″·00 E. Since A. 1. is 4″·0 east of B. 1. this assumption is equivalent to adopting 34° 54′ 04″ E as the longitude of A. 1. On reference to page 36 it will be seen that the latter number is less than the longitude actually found for A. 1. by 38″. But the longitude actually found might subsequently have required a correction as the result of rigorous discussion, so that there were very great advantages in starting with a round number. The finally adopted seconds of longitude could then be readily applied as a correction all through the traverse.

The process just described for finding the longitude of A. 2 on the assumption that that of B. 1. is 34° 54′ 00″ E., is applicable to the computation of A. 3. from A. 2. and so on to A. 13., with certain exceptions, as follows.

The traverse A. 4. to A. 5. was computed from the azimuth of the connecting line, and the known *distance* A. 4. to A. 5. The distance from a triangulation carried out by Mr. Keeling is 8050 metres. We have then

$$\text{diff. lat.} = \frac{8050 \cos A}{L}$$

$$\text{diff. long.} = \frac{8050 \sin A}{T}$$

the symbols having the previous meanings.

The computation is then carried on by the method of latitude and azimuth to A. 9. The short traverse A. 9. to A. 9. *bis* is computed by azimuth and known distance, as for A. 4. to A. 5. The same applies to traverse A. 10. to A. 10. *bis*. The remaining exception is in the connection of A. 12. to A. 13. which is rather more intricate. I have already shown on page 41 the lengths and azimuths of the lines (A. 13.) C. and C F. Starting with the latitude of A. 13. as observed, we calculate back through C and F thus obtaining the diff. lat. and diff. long. of A. 13. and F. We thus have the latitude of F by subtracting the diff. lat. from that of A. 13.

Calculating now by the usual latitude and azimuth method we have the longitude of F from that of A. 12. We then find the longitude of A. 13. from that of F by applying the diff. longitude of A. 13. and F.

CO-ORDINATES OF ASTRONOMICAL STATIONS.

All longitudes in this section are calculated from the arbitrary value assigned provisionally to the Station B. 1. on the shore at Taba.

viz., Longitude of B. 1. = 34° 54′ 00″·00 E of Greenwich.

This course was adopted in order that the computation should not be delayed until a final decision was arrived at as to the definitive longitude of B. 1. For the necessary azimuths and latitudes see pp. 12-16, and 18-25, respectively.

Latitude of B. 1.	29° 29′ 12″·4		
„ A. 2.	29° 31′ 52″·0		
Diff. lat.	159″·6		
Azimuth	61° 22′		
Factor for latitudes	m. 30· 79 per 1″		
„ longitudes	26· 94 „		

$$\frac{159''\cdot6 \times \tan 61^\circ\, 22' \times 30\cdot79}{26\cdot\,94} = \quad -5'\ 34''\cdot1$$

Longitude of B. 1.	34° 54′ 00″·0	
„ A. 2.	34° 59′ 34″·1	E
Latitude of A. 2.	29° 31′ 52″·0	N

Latitude of A. 3.	29° 38′ 31″
„ A. 2.	29° 31′ 52″
Diff. lat.	399″·0
Factor for latitudes	m. 30· 79 per 1″
„ longitudes	26· 91 „
Azimuth	317° 36′ 41″

$$\frac{399 \times \tan 317^\circ\, 36'\, 41'' \times 30\cdot79}{26\cdot\,91} = \quad -6'\ 56''\cdot7$$

Longitude of A. 2.	34° 59′ 34″·1	
„ A. 3.	34° 52′ 37″·4	E
Latitude of A. 3.	29° 38′ 31″	N

Latitude of A. 4.	29° 41′ 09″
„ A. 3.	29° 38′ 31″
Diff. lat.	158″·0
Factor for latitudes	m. 30· 79 per 1″
„ longitudes	26· 89 „
Azimuth	336° 33′ 06″

$$\frac{158''\cdot0 \times \tan 336^\circ\, 33'\, 06'' \times 30\cdot79}{26\cdot\,89} = \quad -1'\ 18''\cdot5$$

Longitude of A. 3.	34° 52′ 37″·4	
„ A. 4.	34° 51′ 18″·9	E
Latitude of A. 4.	29° 41′ 09″	N

Distance from A. 4. to
A. 5. (see p. 38)... ... 8050 metres

m.
Factor for longitudes ... ... 26· 88 per 1″
„ latitudes ... ... 30· 79 „
Azimuth ... ... 354° 21′ 51″

$$\frac{8050 \times \sin 354^\circ\ 21'\ 51''}{26\cdot\ 88} = \qquad -\ 29''\cdot 41$$

$$\frac{8050 \times \cos 354^\circ\ 21'\ 51''}{30\cdot\ 79} = \qquad 4'\ 20''\cdot 2$$

Longitude of A.4.... ... ... 34° 51′ 18″·9
− 29″·4

Longitude of A. 5.... ... ... 34° 50′ 49″·5 E

Latitude of A. 4. ... ... 29° 41′ 09″
4′ 20″·2

Latitude of A. 5. ... ... 29° 45′ 29″·2 N

Latitude of A. 5. ... ... 29° 45′ 29″
„ A. 6. ... ... 29° 53′ 53″

Diff. lat. ... ... 504″

m.
Factor for latitudes ... ... 30· 79 per 1″
„ longitudes ... ... 26· 87 „
Azimuth ... ... 349° 28′ 52″

$$\frac{504'' \times \tan 349^\circ\ 28'\ 52'' \times 30\cdot 79}{26\cdot\ 87} = \qquad -\ 1'\ 47''\cdot 3$$

Longitude of A. 5. ... ... 34° 50′ 49″·8
− 1 47″·3

Longitude of A. 6.... ... ... 34° 49′ 02″·5 E
Latitude of A. 6.... ... ... 29° 53′ 53″ N

Latitude of A. 7.... ... ... 30° 06′ 58″
„ A. 6.... ... ... 29° 53′ 53″
Diff. lat.... ... ... 785″

m.
Factor for latitudes ... ... 30· 79 per 1″
Factor for longitudes ... ... 26· 83 „
Azimuth ... ... 333° 50′ 52″

$$\frac{785 \times \tan 333^\circ\ 50'\ 52'' \times 30\cdot 79}{26\cdot 83} = \qquad -\ 7'\ 22''\cdot 4$$

Longitude of A. 6. ... ... 34° 49′ 02″·5
„ A. 7. ... ... 34° 41′ 40″·1 E
Latitude of A. 7. ... ... 30° 06′ 58″ N

Latitude of A. 8.	30° 22′ 14″
„ A. 7.	30° 06′ 58″
Diff. lat....	916″

	m.	
Factor for latitudes	30·79	per 1″
Factor for longitudes	26·70	„
Azimuth...	161° 59′ 32″	

$$\frac{916 \times \tan 161^\circ\, 59'\, 32'' \times 30{\cdot}79}{26{\cdot}70} = -\,5'\, 43''{\cdot}4$$

Longitude of A. 7....	34° 41′ 40″·1	
Longitude of A. 8....	34° 35′ 56″·7	E
Latitude of A. 8....	30° 22′ 14″	N

Latitude of A. 9.	30° 29′ 39″
„ A. 8.	30° 22′ 14″
Diff. lat....	445″

	m.	
Factor for latitudes	30·79	per 1″
Factor for longitudes	26·70	„
Azimuth...	339° 17′ 18″	

$$\frac{445 \times \tan 339^\circ\, 17'\, 18'' \times 30{\cdot}79}{26{\cdot}70} = -\,3'\, 14''{\cdot}0$$

Longitude of A. 8....	34° 35′ 56″·7	
Longitude of A. 9....	34° 32′ 42″·7	E
Latitude of A. 9....	30° 29′ 39″	N

Distance A. 9. to A. 9. *bis.* 4982 metres (see p. 39).

	m.	
Factor for longitudes...	26·70	per 1″
Factor for latitudes	30·79	„
Azimuth...	138° 19′	

$$\frac{4982 \times \sin 138^\circ\, 19'}{26{\cdot}70} = -\,2'\, 04''{\cdot}1$$

Longitude of A. 9....	34° 32′ 42″·7	
Longitude of A. 9. bis	34° 30′ 38″·6	E

$$\frac{4982 \times \cos 138^\circ\, 19'}{30{\cdot}79} = +\,2'\, 00''{\cdot}8$$

Latitude of A. 9.	30° 29′ 39″	
Latitude of A. 9. bis	30° 31′ 39″·8	N

Latitude A. 10. ... ... 30° 39′ 03″
„ A. 9. *bis*... ... ... 30° 31′ 40″
Diff. lat. ... ... 443″

m.
Factor for latitudes ... ... 30·79 per 1″
„ longitudes ... ... 26·66 „ 1″
Azimuth ... ... 328° 23′ 13″

$$\frac{443 \times \tan 328^\circ\ 23'\ 13'' \times 30{\cdot}79}{26{\cdot}66} = \qquad -\ 5'\ 14''{\cdot}9$$

Longitude of A. 9. *bis* ... ... 34° 30′ 38″·6
Longitude of A. 10.... ... ... 34° 25′ 23″·7 E
Latitude of A. 10.... ... ... 30° 39′ 03″ N

Distance A. 10. to A. 10. *bis*... ... 5,500 metres

m.
Factor for longitudes ... ... 26·63 per 1″
„ latitudes ... ... 30·79 „ 1″
Azimuth ... ... 260° 0′

$$\frac{5{,}500 \times \sin 260^\circ\ 0'}{26{\cdot}63} = \qquad +\ 3'\ 23''{\cdot}1$$

Longitude of A. 10.... ... ... 34° 25′ 23″·7
Longitude of A. 10. *bis* ... ... 34° 28′ 46″·8 E

$$\frac{5{,}500 \times \cos 260^\circ\ 0'}{30{\cdot}79} = \qquad 31''{\cdot}0$$

Latitude of A. 10. ... ... 30° 39′ 03″·0
Latitude of A. 10. *bis* ... ... 30° 39′ 34″·0 N

Latitude of A. 11. ... ... 30° 51′ 37″
„ A. 10. *bis* ... ... 30° 39′ 34″
Diff. lat. ... ... 723″

m.
Factor for latitudes ... ... 30·79 per 1″
„ longitudes ... ... 26·63 „ 1″
Azimuth ... ... 336° 23′ 06″

$$\frac{723 \times \tan 336^\circ\ 23'\ 06'' \times 30{\cdot}79}{26{\cdot}63} = \qquad -\ 6'\ 05''{\cdot}5$$

Longitude of A. 10. *bis* ... ... 34° 28′ 46″·8
Longitude of A. 11.... ... ... 34° 22′ 41″·3 E
Latitude of A. 11.... ... ... 30° 51′ 37″ N

Latitude of A. 12.	30° 57′ 42″
„ A. 11.	30° 51′ 37″
Diff. lat.	6′ 05″ = 365″
Factor for latitudes	m. 30·80 per 1″
„ longitudes	26·54 „ 1″
Azimuth	189° 57′ 02″

$$\frac{365 \times \tan 189^\circ\ 57'\ 02'' \times 30{\cdot}80}{26{\cdot}54} = \quad + 1'\ 14''{\cdot}3$$

Longitude of A.11....	34° 22′ 41″·3	
Longitude of A.12....	34° 23′ 55″·6	E
Latitude of A.12....	30° 57′ 42″·0	N

Latitude of F (see p. 48)	31° 15′ 03″·1
„ A. 12.	30° 57′ 42″·0
Diff. lat.	1041″·1
Factor for latitudes	m. 30·80 per 1″
„ longitudes	26·54 „ 1″
Azimuth	336° 15′ 35″

$$\frac{1041{\cdot}1 \times \tan 336^\circ\ 15'\ 35'' \times 30{\cdot}80}{26{\cdot}54} = \quad - 8'\ 51''{\cdot}4$$

Longitude of A.12....	34° 23′ 55″·6	
Longitude of F	34° 15′ 04″·2	E
Latitude of F	31° 15′ 03″·1	N

DIFFERENCE OF CO-ORDINATES OF A. 13. AND F.

[for the logarithms in this computation see p. 41].

(a) *Co-ordinates of C relative to A.13.*

	East.		North.	
log (A. 13.) C ...	3· 365 2105		3· 365 2105	
log sin Z	$\bar{1}$· 956 1683	log cos Z	$\bar{1}$· 630 9698	Z = 64° 41′ 20″
Sum	3· 321 3788		2· 996 1803	
Nat. No.	m. − 2095· 9		m. + 991· 2	

(b) *Co-ordinates of F relative to C*

	East.		North.	
log C F	3· 892 0864		3· 892 0864	
log sin Z	$\bar{1}$· 804 7082	log cos Z	$\bar{1}$· 886 5884	Z = 39° 37′ 50″
Sum	3· 696 7946		3· 778 6748	
Nat. No.	m. + 4975· 0		m. − 6007· 2	

(c) *Co-ordinates of F relative to A. 13.*

East.	North.
m.	m.
− 2095· 9	+ 991· 2
+ 4975· 0	− 6007· 2
+ 2879· 1	− 5016· 0

(d) *Conversion to arc* ($d\varphi$, $d\lambda$).

$$d\lambda^* = \frac{2879\cdot1}{26\cdot40} = +\ 1'\ 49''\cdot0 \qquad d\varphi = \frac{-5016\cdot\ 0}{30\cdot\ 80} = -\ 2'\ 42''\cdot9$$

Latitude of A. 13.	31° 17′ 46″·0	
Latitude of F...	31° 15′ 03″·1	
Longitude of F	34° 15′ 04″·2	E
− $d\lambda$...	− 1′ 49″·0	
Longitude of A. 13.	34° 13′ 15″·2	E
Latitude of A. 13.	31° 17′ 46′	N

7.—DEFINITIVE POSITIONS.

The definitive longitudes are formed from those exhibited in the preceding six pages by applying to them the systematic corrections arrived at by Mr. J. I. Craig (pp. 85-86).

The latitudes require of course no such systematic corrections, and are exhibited as found. When the result of direct observation, they are given to the nearest second, but when derived by triangulation from a station in known latitude, decimals are shewn, not that they are then really more accurate, but to prevent accumulation of small errors in computation. The Marble Boundary Pillars at Rafa are 80 metres due north of the astronomical Station A. 13.

The longitudes of stations projected on the map as signed by the Commissioners, were obtained by adding to those exhibited in the preceding six pages, and which are collected in the first column of the subjoined table, the constant adjustment + 52″. This has the effect of making the longitude of A. 13. found by traverse from arbitrary datum, agree with the telegraphic longitude of p. 36. It amounts to assuming that the telegraphic longitude is indefinitely superior to that found by transport of chronometers from Suez to Taba. If the opposite

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(* The plus sign indicates F *east* of A. 13.)

hypothesis had been formed the constant adjustment would have been + 38″, which differs but little from 52″. In the Table of definitive latitudes and longitudes which follows, the adjustment used is not + 52″ but + 65″, the excess (or 13″) being due to Mr. Craig's revision of the telegraphic longitude of Rafa (see p. 85). The adjustment + 65″ holds in all cases except that of A. 10 at which station the adjustment required is 44″ in order to obtain the longitude found by Mr. Craig on p. 86.

TABLE OF DEFINITIVE LATITUDES AND LONGITUDES.

STATION.	Longitude E (traverse). *	Adjustment. †	Final longitude.	Latitude N.
A. 1.	34° 54′ 04″	+ 65″	34° 55′ 09″	29° 29′ 16″·0
B. 1.	34° 54′ 00″	65	34° 55′ 05″	29° 29′ 12″·4
A. 2.	34° 59′ 34″·1	65	35° 00′ 39″	29° 31′ 52″
A. 3.	34° 52′ 37″·4	65	34° 53′ 42″	29° 38′ 31″
A. 4.	34° 51′ 18″·9	65	34° 52′ 24″	29° 41′ 09″
A. 5.	34° 50′ 49″·8	65	34° 51″ 55″	29° 45′ 29″·2
A. 6.	34° 49′ 02″·5	65	34 50′ 08″	29° 53′ 53″
A. 7.	34° 41′ 40″·1	65	34 42′ 45″	30° 06′ 58″
A. 8.	34° 35′ 56″·7	65	34 37′ 02″	30° 22′ 14″
A. 9.	34° 32′ 42″·7	65	34 33′ 48″	30° 29′ 39″
A. 9.*bis*...	34° 30′ 38″·6	65	34 31′ 44″	30° 31′ 39″·8
A. 10.	34° 25′ 23″·7	44	34 26′ 08″	30° 39′ 03″
A. 10.*bis*...	34° 28′ 46″·8	65	34 29′ 52″	30° 39′ 34″·0
A. 11.	34° 22′ 41″·3	65	34 23′ 46″	30° 51′ 37″
A. 12.	34° 23′ 55″·6	65	34 25′ 01″	30° 57′ 42″
A. 13.	34° 13′ 15″·2	65	34 14′ 20″	31° 17′ 46″
Marble Pillars at Rafa...	34° 13′ 15″·2	65	34 14′ 20″	31° 17′ 48″·9

* To the arbitrary origin B. 1. taken as 34° 54′ 00″·00 E.

† From Mr. CRAIG's discussion.

DEMARCATION OF THE TURCO-EGYPTIAN BOUNDARY.

8.—Instructions.

On returning to Cairo I resumed ordinary duty from which I was summoned by telegram on September 25. I then received instructions to the effect that the agreement would probably be signed in a few days and that I was to hold myself in readiness to assist in the demarcation of the frontier in accordance with the agreement by putting down semi-permanent marks on the lines previously selected. On the 28th September I had an interview with H. B. M. Chargé d'Affaires at Alexandria, and was shown the draft agreement which enabled me to make the necessary preparations. The detail as to method decided on, and equipment will be found on page 54. By October 1 all was in readiness, and on receiving a telegram to the effect that the agreement had been signed I left for Port Said and sailed in H.H.S. "Abd el Moneim" on October 2, reaching Rafa on the 3rd.

9.—Outline of demarcation operations.

The demarcation operations were on the whole uneventful. The main camp was not able to break up at once, so that the first two days' work was done from Rafa as base, returning to camp at night, and on that account rather less rapid progress was made than afterwards. The first traverse ran across a wavy stretch of dunes from A.13. to A. 11. On the third day we reached A.11., keeping the line perfectly straight. The line was marked by telegraph poles at distances of from 1 to 2 ½ kilometres and intervisible. These were set in position at the place indicated by me, and agreed to by the Commissioners on both sides, the working party being under the direction of a Yusbashi of the Egyptian Army, belonging to the Department of Works.

We reached A.11. at sunset, and some uncertainty prevailed as to where we should find the main caravan. On arrival at El Auga near A. 11. we heard from the Turkish depôt that it had gone on to Birin, so though somewhat tired with operations which had begun at 5.30 a.m. and continued all day, we had to march again, and found the camp at 10.30 p.m.

From Birin camp next morning I went back to A.11. and carried the line from that point half way to A.10. *bis*, the next point on the boundary, and again the next day at noon to A. 10. *bis* itself. This traverse presented no difficulty, the mountain Ras el Ain (A. 10. *bis*) being visible all the way. The caravan had mean time moved to water at Ain el Quderat, and we rejoined it at night, having in the afternoon carried the line half way towards A. 9. *bis*. It might have been more convenient if the caravan had gone to water at Ain Qadis, but we were not sufficiently confident of being able to find our way there to join it, if sunset overtook us at work, as it usually did.

Leaving the camp at Ain el Quderat next morning the Commissioners and survey party returned to the scene of the previous evening's work, the caravan taking the easier route through the plains to Mayein. We took two days' supplies with us, to last till a junction was re-effected. The traverse was carried on over some of the most difficult country which we had to encounter in the whole demarcation, viz : across the upper branches of the Wadi Ain Qadis. Emerging on to the level high plateau of Gebel Kharuf, it was found that we had carried the line too far to the east by about 500 metres, the mistake being due largely to the difficult nature of the ground. If it had been possible to make a preliminary traverse, the errors would have been avoided, but on both sides there was the greatest anxiety to bring the work to a conclusion, without the loss of time involved in such preliminary traverse. A compromise was made, the last two telegraph posts being moved so as to bring them into the line again, and this was accepted by the Commissioners on both sides. It may here be recalled that the distance from A. 10. to A. 10. *bis* was somewhat less accurately known than in other traverses and that the points A. 10. *bis*, A. 9. *bis* were not intervisible, the latter not being sighted till the party arrived within 1 kilometre of it. These facts taken with the roughness of the ground made the demarcation a matter of extreme difficulty.

Next morning the traverse was carried without trouble to A. 9. on the south scarp of Gebel Kharuf a distance of only 5 kilometres on easy ground, after which began the task of joining up to Mayein.

The point near Mayein to which the boundary runs, is defined in rather a different way to others, in the text of the agreement. Previous beacons had been at astronomical points, but this one is defined as a point possessing certain qualifications (see the text of the agreement on page 3). It was plainly essential to strict demarcation, that I should go first to Mayein, select a point satisfying the said conditions and determine its geographical position, after which it would have been easy to connect it to A. 9. I put these matters before the

Commissioners, but they decided they would only establish one point between A. 9. and the place in question, and that the time necessary for such preliminaries could not be spared. I was obliged therefore to make as good a selection as I could with the help of the map and my knowledge of the topography. The search for a suitable point gave us the hardest day's work of the whole expedition. The country between Wadi Lussan and Mayein is deeply intersected with a complicated system of wadis, and we several times appeared to have lost our way completely before we arrived at a point from which we could see to the north A. 9. and to the south a hill overhanging the hollow basin of Mayein and appearing to satisfy the necessary conditions. Having set up a beacon here, a long detour via Wadi Makhsus had to be made and across parallel wadis before we arrived at the hill in question just at sunset. This hill fortunately satisfied the necessary conditions, so we set a telegraph post on it, and rode into camp at Mayein. The task immediately before us was however a simple one from a surveyor's point of view, *viz.*, to set up one telegraph post in the line joining our last point to A. 8. and to set up one more at A. 8. itself on the high summit of Gebel Semawi. The line in question is a short one. I therefore in the morning sent up a work party with a telegraph pole to await me at the top of Semawi, while I located the position of the intervening point and marked it by a flag. I then sent a second party in the afternoon to set up a telegraph pole where I had set up a flag and accompanied by Mohammed Fahmy Bey the indefatigable second Turkish Commissioner, we climbed Gebel Semawi. There I pointed out to him the cairn which we had built on occupying Semawi as an astronomical station, and the telegraph post was set up. I also showed him by the theodolite that the intermediate post in the basin of Mayein was duly in line with us and the termination of the previous day's work. All was thus ready for beginning the great traverse southwards from Mayein. I was particularly anxious to settle the beaconing of A. 8. before this began, as otherwise much time would have been lost and the expedition would probably have had to return into Mayein instead of pushing forward as it was enabled to do. I must express my thanks to Fahmy Bey for it was a *sine qua non* that a Turkish Commissioner should be present, and he forewent a well-earned rest to carry the matter through.

From Mayein to the Mufraq el Aqaba the demarcation was a simple matter, but the journey was rendered difficult by the absence of water. From this cause and also from the desirability of bringing the whole business to a conclusion, movements were exceedingly rapid, and 70 kilometres of boundary were laid out in two days, while the whole distance to Thamelet near the Mufraq was settled in less than three.

On the morning of Oct. 14 we struck the line A. 8.—A. 7., and moving rapidly along it without incident arrived with complete precision at A. 7. just at sunset. The caravan had taken the more westerly route by the Ghaza road camping at Thamelet el Swelma and here, after a short search in the dark, we found it, and stopped for the night. Next morning we separated again, the caravan to go by Ghaza road to the Mufraq, and we along the boundary to Gebel Um Quf and thence to Gebel Bir Said and Ras Radadi near the Mufraq. On that day we laid out 40 kilometres of boundary without incident. When we had gone 10 or 15 kilometres we sighted Gebel Um Quf so that we ceased to travel by compass, but steered straight for our objective. Bivouacking under the slopes of Um Quf we made the summit early next morning and the remainder of the operations as far as Thamelet el Radadi call for no comment; the summits to be beaconed were within easy distance of one another and visible throughout, so that the selection of intervening points in the plain required practically no technical help.

We found the caravan at the Mufraq and next morning started on the operations between Thamelet el Radadi and the sea. These are of quite a different character from the preceding, and the text of the treaty must be carefully studied to appreciate them, but they presented no difficulty. By the afternoon there was nothing left to do but to place the beacons on the eastern margin of Wadi Taba. The technical part of my work was finished, as the treaty describes the position of these beacons in such a way that trained assistance was unnecessary. A delay here occurred for a whole day as by an oversight the Turkish depot at the Mufraq had not yet received orders to vacate that station, which was now in Egyptian territory. Next morning they had left and we descended into Wadi Taba. I accompanied the Commissioners and assisted them generally, but as explained no technical assistance or instrumental work was required. Just at sunset the last point was placed on Ras Taba and we boarded H. H. S. "Nur el Bahr" which was awaiting us in the Gulf.

10.—TECHNICAL METHODS USED IN DEMARCATION.

The problem before us in demarcation was in most cases to march in a straight line from a station of known geographical position to another likewise known. The two were not necessarily intervisible or ceased to be visible to the surveyor on the route between. The geographical positions being known the bearing of the traverse line could be computed, and afterwards checked by applying a protractor to the map. Furnished with the requisite azimuth three possible alternatives presented themselves to me.

(*a*) A theodolite is set up with great care in the correct azimuth from the starting point and say 2 kilometres from it, astronomical measures being used to fix the bearing. The theodolite is reversed and so a new "forward" station is established in the correct azimuth and, say, 1 kilometre forwards. This process is repeated again and again, until the destination is reached.

(*b*) Two marks having been set up in the right azimuth, a third is set up by alignment, using a field glass.

Before coming to the third I will state the objections to these two. In using the first it was always found that owing to the deceptive nature of the topography aggravated by mirage, that the "forward" party had been signalled to halt at an unsuitable station. On arriving one would find a fold in the ground 50 metres further on barring the forward view, but which might have been used itself as a site for a station. In fact all methods involving the use of "forward" parties are troublesome where there is much mirage unless the members of the forward party are sufficiently trained to use their judgment to some extent as to halting-places. Again the errors of the above method are evidently accumulative.

The second method is evidently restricted to cases where more than one back station can be seen which was not often the case in the noonday mirage, and it is also subject to cumulative errors. At every station the work party set up a telegraph pole, and it was not to be expected that it would be set up within a few centimetres of the spot selected.

Supposing that the first two stations were 500 metres apart and the interval from second to third 2,500 metres and that the first beacons were each set up one metre in error by the work party, we should be ten metres out on the third, if alignment was used. Nevertheless, this method, used with judgment and in suitable cases, is capable of occasionally replacing the method about to be described and thereby economizing much time.

(*c*) The method almost exclusively used. I relied on the fact brought out in the survey operations* that the magnetic variation is wonderfully constant, approximating to 2° W. I had with me a six-inch Cooke's theodolite with reading microscopes and furnished with a good compass needle. This was set up in a position which was estimated to be correct and a magnetic reading was taken on the starting-point. If the reading differed much from the desired one, a rapid calculation was made and the instrument was set up again in the position indicated by this computation. If the reading was now very nearly correct, a computation was made, a peg was driven in at the spot indicated and the work party were ordered to dig at that point. The ordinary distance between two telegraph poles was 1½ kilometres and therefore an error of about 5 metres would appear as 10′ on the theodolite. The usual rule was that if the reading was more than 10′ different from the required value the theodolite was moved and a better approximation made, but if less the work was started at the estimated distance to the right or left of the theodolite.

Frequently when a position had been obtained by this method it was possible to see two or more posts behind the last one, and to satisfy oneself independently that they were in line. As the posts were 5 metres high it was possible to estimate that the alignment by magnetic reading was good to less than 2½ metres or half the height of a post. As the method is essentially free from cumulative error, the error at the end of a traverse of 30 kilometres would not amount to more than 12 metres, and this is in agreement with what was observed on such lines as those from A. 13. to A. 11. where the method had a good trial. In other cases we cannot judge of the accuracy so well as the objective was visible for a great part of the way and naturally I elected to steer for the objective when visible rather than rely on compass readings.

The success with which the objectives were ultimately reached encourages us to believe that the astronomical positions are substantially accurate.

The method of progress described was used all the way from Rafa A. 13. to Ras el Radadi A. 3. After this the hill above Thamelet el

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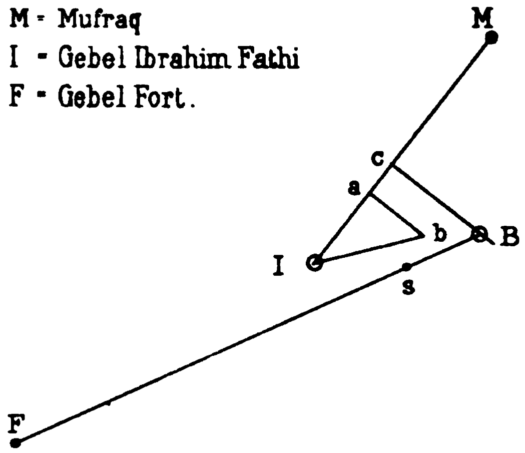
* See page 66.

Radadi was beaconed in accordance with the treaty. The next point is specially defined by the treaty (see page 3) and was located as follows :—



A flag was placed at M and a point *a* was taken in the alignment and a base *ab* measured so that angle I *ab*=90° and I *ba*=45°. Thus I *a*=*ab*. Now *ab* was 160 metres long. Accordingly by placing a mark at *c* in the alignment of I M such that *ac* is 40 metres we get I*c* in accordance with the treaty. An offset *c*B was made at right angles to IM and a flag was placed at *s* in the line joining FB and due east of I. The distance I*s* was found not be exceed 200 metres so that B satisfies the terms of the treaty, and a beacon was erected there. Another was erected at *s* and yet another at F. The angles were measured with a prismatic compass and the lengths with a chain. It was not possible to measure I*c* directly as the ascent to I was steep.

The remaining beacons were erected at suitable points on the east cliffs of Wadi Taba, and at the point where they strike the gulf of Aqaba. They were chosen by the Commissioners and technical assistance was not necessary.

I append to my report on the delimitation and demarcation, the journals made in the field and some magnetic results (pp. 57-66).

E. B. H. Wade.

JOURNAL OF OPERATIONS CONNECTED WITH DELIMITATION OF FRONTIER BETWEEN SYRIA AND EGYPT, 1906.

May 16.—Received telegraphic instructions to proceed from Alexandria to Cairo at once to join Aqaba Boundary Commission. Caught the noon train leaving assistant to come in by night train with theodolite, etc. Arrived at Survey Department, too late to see Director General, but found a letter with instructions and stating Mr. Keeling is appointed as topographer. Remainder of day fitting out.

May 17.—Forming camp at Giza. Afternoon went to Observatory and discussed arrangements with Mr. Keeling. Remainder of day fitting out.

May 18.—Interview with Acting D. G. at Survey Department, and with Mr. Craig. Drew most of necessary stores. Afternoon packing.

May 19.—Interview with Major Owen who expects to leave for Suez on Wednesday. Arranged to start myself on Tuesday, so as to have time for rehearsals there. Fitting out and packing.

May 20.—Mr. Keeling arranged to do same and I notified Major Owen accordingly. Fitting out and packing.

May 21.—All kit removed to Cairo station, and forwarded to Suez with two chainmen.

May 22.—Left for Suez docks at 11 a.m. Made an azimuth observation by way of rehearsal, and set up a camp. The spider lines of theodolite were much damaged by jolting and I decided to replace them. Scaled off position of my observing station from the Admiralty charts which are adjusted to Sir D. Gill's longitude.

May 23.—Successfully rewebbed theodolite, and made observations for local time by the sun's altitude. At night determined the same by equal altitude of stars. Compared all chronometers. They have changed a good deal *inter se* but the mean is good (as shown by agreement of longitude found with that of map). The calculation of sun's altitude was made at once, and the full computation of the star observations was complete by 11. 30 p. m.

May 24.—Continued various computations all the morning. At 3. 30 p. m. reckoned and recomputed the sun's altitude. At night reobserved stars of previous night. Placed most of the kit on the "Nur el Bahr" (Coastguard cruiser).

May 25.—Placed remainder of kit on "Nur el Bahr," sailed at about 11. 30. Continued computations on board, and compared all chronometers.

May 26.—Compared chronometers. At 5 p. m. anchored in Gulf of Aqaba which we had entered at dawn. Went ashore to the granite island of Geziret el Faraun. This granite appears a typical grey quartz felspar and black mica. On the mainland a fine exposure of contorted limestone faulted against granite. Arranged to be landed at Taba to-morrow morning as early as possible to settle longitude difference from Suez.

May 27.—Early start for land at Taba. Selected a site for longitude station and described it as A. 1. Observed sun's altitude with sextant pointings a. m. Went for a very long walk towards Aqaba along the shore with sketch book. Granite comes all the way close to shore, but beach of 100 to 300 metres separates them. Observed sun again p.m. under exactly similar conditions. "Nur el Bahr" called for us at 8. 30 p. m. and took us to Aqaba where Cook's caravan is standing in readiness for us. This is a departure from the programme which provided we should anchor again off Farun Island, and somewhat upsets the arrangements I had made, for astronomical observations at Taba. Computed longitude of Taba till 10. 30 p. m.

May 28.—Continued computation. The a. m. and p. m. observations are in agreement, and taken together should establish the longitude from Suez ; the result is probably as good as can be obtained by chronometer transport. Made a reconnaissance for base at Aqaba and to fix its azimuth so that Mr. Keeling could close his topographic survey of the coast on to it. Finally I was obliged to take it quite near the camp as otherwise the hill at Taba (adjacent to my astronomical station A. 1. and described as B. 1.) is not visible. Just at sunset Mr. Keeling closed on to the selected line, and at night I determined its azimuth. Started to make other observations, but interrupted by clouds. Computed azimuth before retiring.

May 29.—El Bimbashi Potts called in the morning and kindly supplied some information as to position of Aqaba Fort by Austrian survey ship "Pola" $\lambda = 34^\circ\ 59'\ 20''$ E and $\varphi = 29^\circ\ 31'\ 15''$ N. Taking the most probable $d\lambda$ as $1'\ 45''$, $d\varphi$ as $1'\ 15''$ we have Taba $34^\circ\ 53'\ 45''$ ("Pola"). In round numbers the available longitudes seem to be "Pola" $34^\circ\ 53\frac{1}{2}'$, older surveys $34^\circ\ 55\frac{1}{2}'$, present survey $34^\circ\ 54\frac{1}{2}'$. The camels promised did not come, so I had to defer my trip back to Taba. Instead I sketched with pedometer and prismatic compass as far as caracol beyond Aqaba Fort and enlarged it to a scale 1: 10,000. In the evening I made a complete set at Aqaba for latitude and time.

May 30.—All morning and early afternoon computing. Later removed to Taba : observed for latitude and time and azimuth at A. 1. [This azimuth was not used in the computation of the traverse for which it is not needed. It is therefore omitted].

May 31.—In the morning started a topographical sketch map of Wadi Taba, returned to camp at Aqaba, observed there (at A. 2.) for latitude and time. Compared watches.

June 1.—With the help of the azimuth line already fixed observed bearing of Taba B. 1 on which I had placed a white flag the previous day. Calculations till 2 p. m. I then placed on a graticule of 1: 250,000 the astronomical positions so far fixed, also the supposed position of El Rafa, and drew the provisional boundary on this, viz. a straight line from Marashash on the N.W. corner of the Gulf of Aqaba to El Rafa. Any future positions as found were to be plotted on this graticule. Equipped with prismatic compass and pedometer, started on a three days' sketching expedition on the wadis Taba and Tueba. Left Aqaba at 5.30 p.m. leaving assistant with instructions to pack effects in the main camp. Arranged to rejoin main camp again at its next halt on the Mufraq. Escort 2 Sudanese soldiers and Bedawi guide.

June 2.—Starting at 6 a. m. sketched all the way up Wadi Taba and down Wadi Tueba. Back by shore to Taba and up Wadi Taba again. Rejoined camels at a point midway between the origins of Wadi Taba and Wadi Tueba, at 10 p. m.

June 3.—Went down Wadi Tueba again to Taba, then up Wadi Tueba again, checking sketches. In neither wadi is there any new geological feature. Limestone faulted against granite or resting on it with red basal conglomerate and grit, then passing through a reddish freestone to yellow limestone often nodular, unfossiliferous.

Folding on a magnificent scale, especially half-way up Wadi Taba. After finishing with Tueba, surveyed all the way up to Nagb Taba. Fossils at Nagb Taba in limestone, also green copper staining. Slept at Nagb.

June 4.—Marched in to main camp at Mufraq, sketching as I went. The last 3 hours on a vast limestone plain at greatest altitude yet reached. On arrival at Mufraq I was able to obtain a general view of the district covered, the general slope to the sea being well shown.

June 5.—Most of day working up topography. Towards evening left for Jebel Radadi to observe at station A. 3. Completed a set for latitude, time, and azimuth of lamp. Returned 11 p. m.

June 6.—In morning observed at Gebel Radadi the angles made by lines A. 3—A. 2 and A. 3—A. 4 with the line of observed azimuth, thus obtaining azimuths of A. 3—A. 2 and A. 4—A. 3. The station A. 4 has been beaconed in advance by Mr. Keeling, and is at Gebel Bir Said. It is rather near to A. 3 for progress by latitude and azimuth. Made preparations for early start to-morrow morning. Mr. Keeling left in the afternoon, the programme being that he would communicate with me from time to time explaining what points he required to be determined astronomically to support his topography. He intended to traverse approximately along the provisional boundary, guided by prismatic compass, but was not in a position to give a more detailed programme in advance.

June 7.—Left at 6 a. m. Mufraq for Gebel Bir Said (A. 4.). The track lies at first along the Ghaza road till a line of volcanic rocks is passed. It then turns sharply to the east till Bir Said, a limestone hill, precipitous to the south, sloping gently to the north. Complete set of astronomical observations.

June 8.—Found at dawn that all the men and camels had gone together to get water. They left at 4 a.m. and did not return till 3 p.m. Thus I was unable to leave my station although a messenger arrived from Mr. Keeling indicating new point. I tried to rejoin main camp when camels finally arrived, but met another messenger from Mr. Keeling at about 12 kilometres from Bir Said saying he was sending supplies to A. 4. Returned to Bir Said very late and had much difficulty in finding it in the dark. Appointment with Mr. Keeling at Gebel Um Quf to the north, next morning.

June 9.—Left Bir Said at 5 a. m. and found Mr. Keeling at about 8. 30 at the top of Gebel Um Quf. Settled programme for the next few days. By arrangement with main camp there is to be a depot of food at Ain Ghabia. I observed the sun's azimuth at Gebel Um Quf and thence the azimuth of line A. 5—A. 4. This with the distance found by Mr. Keeling gives the coordinates of the point. I left Gebel Um Quf at 5 p.m. and followed the route agreed upon via Wadi Eqfi and Ghabia. The road is a deep limestone gorge, and at sunset we emerged a wide plain or lake basin bounded by limestone hills to the east and stretch far to the west. Camped at dark a short distance out of Wadi Eqfi.

June 10.—Continued on route and found Mr. Keeling triangulating on Ge Abu Qeradi where he had found a suitable site for astronomical station A. Camped on top of Abu Qeradi and observed full set there at night, Mr. Keeli having left for Ain Ghabia at 2 p. m.

June 11.—Moved to Ain Ghabia and watered. The march was over an undula ing limestone plain covered with black flints (G. Abu Qeradi was similarly cover with flints and there are frequent courses of flint in its section, as seen on t east face. It slopes gently to the plain on the west). Ground is still of the sa character.

June 12.—Continued route agreed upon, and soon after crossing W. Gerafi m Mr. Keeling and topographical party with news that they had been held up by party of Bedawin well armed and 150 strong. In the end they returned all th stores which they had seized. In addition supplies were somewhat low so it wa agreed to move as quickly as possible into Mayein where the main camp wa waiting for us, without stopping for the present to observe at A. 7 a small conica hill near the site of the raid. We left Gerafi together at noon, and marched til sunset camping at W. Abu Elegi where we met some of the camels from th Mayein camp grazing. The character of the ground was the same as in the traverse of the previous day, but we passed some cultivation at 4. 30 p.m., and about the same time some curious banks of gravel. A little before sunset we descended into what appeared to be a lake basin, the walls of which were composed of a white calcareous rock of very soft and floury consistency. The basin was fairly surrounded by hills and a large number of small Wadis had been formed around the margin.

June 13.—Two hours walk brought us to Mayein in time for breakfast. I rested for the morning and later I observed the sun, at noon for latitude and at 4 p. m. for local time. The object of these observations [which are not included in the report] was to obtain a provisional longitude, in time for a despatch which was just being sent off, relative to positions of Mayein, Ain Qadis, and Qoseima. I calculated results at once and gave a provisional value for the longitude of Mayein shewing it well on the west of the geometrical boundary. Made fuller computations in the evening. Determined error of prismatic compass for Mr. Keeling who starts early to-morrow morning for a rapid reconnaissance as far as Qoseima.

June 14.—A heavy day's computation; put results for A. 4. and A. 5. in final form, and began those for A. 6. without reaching final conclusion. Mr. Keeling left early as arranged yesterday.

June 15.—Completed reduction of A. 6. I then carefully verified the solar computations at Mayein and it is now possible to compute the longitude by difference from A. 2., A. 3., A. 4., and A. 6. The four results are in surprising agreement when one takes the mean of all the watches although the individual watches are rather discordant. This shows that the mean rate of the 5 watches is little disturbed by transit, and it also increases confidence in the Taba longitude. In the evening I did a complete set of star observations, and worked out the local time. The results confirm the solar longitude. [Astronomical observations at Mayein camp are omitted, as it does not form a link in the chain. The nearest station in the chain is A. 8. on Gebel Semawi overhanging the hollow basin of Mayein. At the time of writing it was thought that we should be obliged to rely on observations at Mayein camp. These observations it may be added are in agreement with those at A. 8.].

June 16.—Brought all computations up to date and plotted positions of stations including Mayein, on the 1 : 250,000 graticule.

June 17.—Climbed Gebel Semawi to station A. 8. It was impossible to see A. 6. from it, as was indeed to be expected. Observed complete set for latitude and time.

June 18.—Returned to camp at Mayein, early. Made a triangulation near the camp with a short chain base. This enables me to compare observations at Mayein camp with those at A. 8. [This work is not shown in the computations for the reasons stated June 15. The comparison was quite satisfactory]. Calculated results at A. 8.

June 19.—Left early to go back to A. 7. which had been left out on the way to Mayein. Distance about 30 kilometres. This point is a curious low cone of limestone rising out of the flint-covered plain, and capped with gravel containing many pebbles of a felspar porphyry. We observed a complete set in a violent wind so strong that the bull's-eye lantern which is almost wind-proof, was extinguished three times.

June 20.—Left early and returned to Mayein by 2 p. m. The chain is now complete as both A. 6. and A. 8. were observed from A. 7. I made at once an approximate calculation of the latitude of A. 7. and of both azimuths and plotted position on graticule.

June 21.—Left 6 a. m. from Mayein with the Commissioners for Gebel Raman [see p. 9]. The main caravan went on to Ain Qadis. A. 9. is on the south flank of Gebel Raman. This curious hill is a high plateau with slight crown and intersected by deep wadis. A strong position and fertile. Flocks abound. The route from Mayein to Raman passes through the prosperous Wadi Lusan. We observed at A. 9. sighting A. 8. with ease and leaving the question of forward sights for to-morrow. The plateau formation is very unfavourable to us as it cuts off the horizon to the north.

June 22.—All the morning given to reconnaissance for a suitable point for a station to be called A. 9. *bis* to enable us to see north. When we secured one, we were much disappointed to find that it would have been possible to see A.8. from it, so that a good deal of unnecessary work had been done. To avoid camping another night on the high ground with only 5 kilometres progress we measured a short base and triangulated from A. 9. *bis* to A. 9. At A. 9. *bis* we built two cairns 2 metres apart and 1½ metres high each. At A. 9. we built one large tower-shaped cairn. I also made sketches of the topography of the summit as far as time permitted. From A. 9. *bis* the route takes us less than 5 kilometres to the N. E. then down the Wadi Ain Qadis which is descended only with much difficulty by loaded camels. Rested at Ain Qadis which had evidently been recently vacated by caravan and resuming march at 6. 30 bivouacked on road to Qoseima at a p about 6 kilometres to N.W. of Ain Qadis.

June 23.—Made an early start and reached Qoseima for breakfast. The ro from Ain Qadis to Qoseima is easy over the low plain with limestone ramp to the east, being a continuation of the plateau A. 9. to A. 9. *bis.* Heavy compu tions, and brought all latitudes and azimuths definitely up to date as well as triangulation of A. 9. to A. 9. *bis.*

June 24.—Computed coordinates up to date and plotted them on graticu Camp due to leave to-morrow at dawn for El Auga. Qoseima is a small *holl* surrounded by limestone hills. Our route to the next astronomical station pas up Wadi Ras el Ain, a fertile and picturesque valley. The guide was ill *acquaint* with the country, but we finally reached Ras el Ain just before sunset, only find that it is much too far east to clear the hills to north of A. 9. *bis.* No *obse* vations were made that night.

June 25.—4. 30 a. m. we rose and took the theodolite up every likely hi to the west of Ras el Ain. At about 7.30 we succeeded in sighting A. 9. *bi* At the same time we saw quite near us a hill on which Mr. Keeling had place a flag in the course of his topographic work. The hill is called Ras el Ain Quderat, and we decided to occupy it. With difficulty we got the theodolite u by 8 a. m. just in time as refraction was beginning to be troublesome. We deter mined the azimuth of A. 9. *bis* by the sun, observed for local time and at noon took the latitude by the sun, though the method is not very favourable to accuracy ten pointings for latitude alone were made to compensate for the lack of precision of solar observations as compared sith stellar.

June 26.—Morning and early afternoon calculating solar observations at A. 10. the latitude being troublesome to reduce owing to the proximity of the sun to the zenith. At 3 p. m. we left for the point A. 11. which is about 3 kilometres out of the camp. Ain Quderat, our last astronomical station, is not visible from *A. 11.* but Ras el Ain which we had originally intended for our 10th station is visible, so that azimuth pointings were made to the flag on its summit. The summit is described as A. 10. *bis* and the distance A. 10. to A. 10. *bis* requires to be known.

June 27.—Fortunately Mr. Keeling is able to supply the necessary data as to A. 10. and A. 10. *bis* from his topographic work, and as the stations are near together little error is likely to follow from their use. I therefore was saved the necessity of returning all the way to Ras el Ain which would have caused much delay and upset arrangements seriously, and at 6. 30 a. m. continued on the way to Khashm el Qarn, the main caravan making for Rafa by a more direct route, via Murabaa. We camped at noon at Khashm el Qarn, and calculated solar results at A. 10. all the afternoon. Observed complete set at Khashm el Qarn at night.

June 28.— Left Khashm el Qarn at 5.30 a.m. for a 30-mile ride to Rafa which we reached at 3 p. m. Calculated all afternoon and evening.

June 29.—Started calculating early and settled solar results at A. 10. Next settled without difficulty the reductions at A. 11. Telegraphic message arrived fixing 30th for exchange of time signals for longitude.

June 30.—By the evening had settled all computations up to date and was ready for longitude work. Observed at Rafa (A. 13.) a long programme of stars, and exchanged time signals while the series was in progress. Observed also for azimuth of a flag placed by Mr. Keeling on the dunes between Rafa and the sea, and described as "point C."

July 1.—From this point Mr. Keeling carried a triangulation to a point F from which he can see Khash el Qarn so that the connection is made complete. I calculated this rather troublesome triangulation and found azimuth of all lines including that of A. 12. to F. Hence the longitude of my station A. 13. at Rafa. A. 13. is 80 metres south of the marble pillars which were held to mark the boundary between Egypt and Syria before the dispute arose. Very shortly after the computation was finished a telegram arrived from Helwan giving the correction to apply to the signals sent from the Observatory.

JOURNAL OF DEMARCATION OPERATIONS.

Oct. 2. 06.—Left Alexandria with kit for demarcation work; arrived Port Said 4 p.m. joined "Abd-el-Moneim."

Oct. 3.—Arrived Rafa 10 a.m. Landed without difficulty, surf being slight. After lunch went out with prismatic compass and checked positions of the marks to north of Rafa shewing course of boundary from Rafa to sea. I plotted these on Major Owen's map as the bearings. Evening calculated bearing from Station A.13. to A.11. from its known latitude and longitude and checked it by working on the map. Observed Polaris with 6" Cooke theodolite, to get relation between apparent magnetic readings and the bearings.

Oct. 4.—Made a reconnaissance along the line of advance for about 7 kilometres. After noon, continued the line of boundary down to the sea from Rafa and caused three telegraph poles to be set up to mark this line.

Oct. 5.—Went with commissioners and set up six more telegraph posts on the line beginning at Rafa pillars where yesterday's work ended. In all we are about 16 kilometres on the way towards A. 11. Returned to Rafa camp at 6 p.m. having left it at 6 a.m. sharp and worked without interval.

Oct. 6.—The caravan left Rafa and began to move along the boundary. Accompanied by Commissioners, I carried the line forward to the fifteenth telegraph post working from 6 a.m. to 6.30 p.m. From this point El Auga but not A.11., is probably visible.

Oct. 7.—Continued on same line and camped with commissioners about ⅔ of the way to A. 11. The country is a sea of rolling dunes, and progress is difficult, much search being necessary to secure intervisible points.

Oct. 8.—Finished on to A. 11. It was not sighted till within about 3 kilometres of the finish. Thus we have gone nearly three days on a straight line. The closure at the end was to within about 3 metres.

Oct. 9.—From A.11. at dawn and carried the line towards A.10. *bis* halting a few kilometres to the south of Birin, where our camp was pitched.

Oct. 10.—Line carried up to A. 10. *bis*. This point is visible all the way so there is no difficulty. Arrived at A. 10. *bis* about noon, we changed the course and set up our posts on the line towards A. 9. *bis*. Went back to camp at Ain Quderat. The Turkish commissioners camped at Ain Qadis.

Oct. 11.—Rode out 2 hours to the point where we ceased work yesterday. Resumed and carried the line across Wadi Ain Qadis. Going extremely bad. The camels with work party made a detour up to the head of the wady, while I went straight along the line across the wady. Arrived on the plateau to the south of the wady (Gebel Kharuf) found that we had deviated too much to the east. A consultation was held, and it was agreed to alter the positions of the last two posts to bring them into line.

Oct. 12.—Carried line from A. 9. *bis* to A. 9. without difficulty as they are intervisible. Then we descended into the Wadi Lusan and across the complex of hills and wadis between it and Mayein. I explained that a preliminary reconnaissance was desirable as the point near Mayein for which we were making was defined in a different manner from the others. It was decided that time could not be spared. The selection of a point proved of great difficulty and we reached Mayein at sunset, thoroughly tired.

Oct. 13.—I arranged that (*a*) I would lay out a line from the turning point of yesterday to A. 8. (*b*) at same time assistant to climb A. 8. with work party and telegraph post. (*c*) I would climb A. 8. with one commissioner to approve the site for erection of telegraph post. This programme went through, but with difficulty as all were very tired after yesterdays' work. The result is that to morrow's work begins in the plains on the line towards A. 7. and we shall be spared from beginning with a climb up Semawi and thus much time will be saved.

Oct. 14.—Left Mayein at down, rode till we struck the line A. 8.—A. 7. in Wadi Geraia and set up our first telegraph post on the way to A. 7. working all day we struck A. 7. with complete accuracy just at dark. As in the first traverse, the objective was not sighted until the last moment. Camped at Thamelet el Swelma.

Oct. 15.—Rode out from camp at 5.30 a.m. till we struck the line A. 7.—A. 5. worked along it all day. A. 5. (Gebel Um Quf) was sighted before we had gone very far so that the work of demarcation was rendered simple. In the afternoon we passed Abu Qeradi on our left at about the charted distance which served as a confirmation of our accuracy, and after sunset we camped on the slopes of Gebel Um Quf, having completed just 40 kilometres in the day.

Oct. 16.—We completed the line to A. 5. without difficulty, then turned towards A. 4. which was clearly visible, then on to A. 3. and then to Thamelet el Radadi. None of these points offered any difficulty as they were known to all the members of the expedition, and the setting up of intermediate beacons was accomplished by alignment on the backward and forward points with the theodolite.

Oct. 17.—Laid out the frontier in the neighbourhood of Gebel Ibrahim Fathi with the help of chain and prismatic compass, so as to conform to the terms of the treaty, and at noon we were prepared to start for Wadi Taba so as to complete duty and sail same night. We found however that by oversight Turkish post stationed at Mufraq point had not received instructions from Aqaba to quit, and a day was lost in waiting for them to evacuate.

Oct. 18—In the morning we found post vacated. Descended into Wadi Taba and set up a beacon on its east cliff at a point from which the beacon on Gebel "Fort" is visible. Then two more along the line of east cliffs of Taba and one at the point where they strike the gulf, and the work was complete. We sailed the same evening, the "Nur el Bahr" having been in waiting in the gulf for the last two days.

MAGNETIC RESULTS.

These formed no part of my original programme and are to be considered as rather a by-product of my azimuth observations than deliberate determinations of the magnetic declination.

A magnetic needle was attached to my 8" Troughton and Simm's theodolite, and was so adjusted that it was in play if the theodolite was reading zero on the magnetic meridian. It was my usual practice in observing azimuths to arrange first that the needle should be in play. If this is done, when one comes to calculate the meridional reading of the theodolite, it will come out identical with the westerly declination at the station, *i.e.* at about 2°. If in any case a value widely different from 2° had been obtained it would have implied either that there was a magnetic abnormality or that some error had been made, and the result would have been re-examined. It will thus be seen that my main object was to have a control against large errors in computation but I give the values for what they are worth. There is no reason however why they should not attain to a precision of about 0°·1. I may mention that the value found at Taba with an absolute magnetometer is in sufficiently good agreement with that found by the theodolite at other stations on the line of march. The results are:—

		Westerly Declination.
Station	A. 3.	2° 6′
„	A. 6.	2° 8′
„	A. 7.	1° 59′
„	A. 10.	1° 47′
„	A. 11.	2° 8′
„	A. 13.	2° 0′

Accepting ordinary magnetic charts as being in their broad features correct, the general line of advance was very nearly along a line of constant declination, and we may therefore probably consider the mean of all the above or 2° 1′ as the approximate value of the westerly declination along the frontier in 1906 June. This is perhaps slightly less than one would have anticipated, but I believe it to be correct within 6′.

E. B. H. W.

THE TOPOGRAPHY OF THE BOUNDARY.

The village of Aqaba lies at the east corner of the square end of the Gulf of Aqaba, and at the extreme south of the Wadi el Araba. Behind the village are steep slopes of talus which lie at the foot of the rugged granitic hills which form the eastern wall of the wadi as far as can be seen from Aqaba. These hills, which are some 2,000 metres in height, are traversed about four kilometres to the north of Aqaba by the road and telegraph line from Maan. This road, which joins the pilgrims' road (Darb el Hagg) from Egypt at Aqaba, proceeds southwards along the shores of the Gulf. Aqaba itself consists of a number of huts standing in a grove of date palms which for three kilometres forms a fringe to the gulf. The fort is a substantial square building of hewn stone. At the time of the expedition, the Turkish troops were encamped on the talus slopes behind the town. Water is obtained in abundance from numerous shallow wells close to the shore-line.

The Wadi el Araba is a level valley four to five kilometres in width, lying between imposing walls of rock. The sand which forms the ground is well covered with wadi grasses and shrubs, and an occasional dom palm tree is met with. A few gazelle were seen in the wadi. A shingle bank, one to two metres in height, runs along the northern end of the gulf. The two walls of the valley are strikingly different in character. As remarked above, the eastern side is formed of fine granitic hills. The western side, which is the eastern escarpment of the flat Sinaïtic plateau, is a tumbled medley of limestone, through which rises an occasional peak of granite. This broken mass of rocks is about five kilometres wide, and is intersected by numerous deep ravines, many of which are impassable to camels. The Wadi el Araba is along the line of a continuation of the great Red Sea fault-line, and the scenery forms a most impressive example of a great fault.

Along the western shore of the gulf between Marashash and Taba and northwards from Marashash are considerable deposits of gravel forming a footing to the steep escarpment.

At the western corner of the head of the gulf, where the Darb el Hagg el Masri enters the plain of the Wadi el Araba, numerous shallow wells have been dug for water, which however is brackish and the Turkish post was watered by mule carts carrying water from Aqaba.

At Taba are two wells of brackish water, and two or three dom palms standing on a small gravel-covered plain. The Wadis Taba and Tueiba, which coalesce behind the hill called Gebel Deneib el 'Er, are exceedingly steep and almost impassable by loaded camels. Great walls of rock stretch across the bottoms of the wadis.

The pass ascending from Aqaba to the plateau forms a part of the former Darb el Hagg from Egypt to Mecca. At first it rises on the gravel slopes with a gradient of 1 in 15. After two kilometres, the rocks are encountered. Through these the road winds, the gradient becoming steeper. Five kilometres from the Marashash, the road turns behind the considerable granite peak (Gebel Radadi). Here a deep ravine, which crosses the road, is spanned by a bridge of good ashlar masonry. From here the road ascends on the top of the hog's back between two ravines with a gradient in places of 1 in 4. After two kilometres the small limestone peak, Gebel Rushdi Pasha, is passed on the left, and the flat Korekra (resting-place) is reached. Finally, by an easy gradient, the plateau (known as el Sath = the roof) is reached, 600 metres above sea level.

From the Korekra steep paths lead down to the well in the Wadi el Radadi. This well is said to be perennial and is sufficient for 30 or 40 men. On reaching the plateau, the road branches in several directions. One branch leads westwards across the perfectly flat plateau towards Nekhl and Süez, forming the Darb el Hagg el Masri. The Darb Ghaza goes off in a north-westerly direction and enters the Gebel Homra, whilst a third road leads along the edge of the plateau and past the eastern end of the same gebel. The view from the Mufraq (place where roads bifurcate or cross) extends for many miles westwards and southwards. To the east it is limited by the low hills 30 or 40 metres high, which intervene between the plateau and the escarpment, like the rim of a tray. On ascending one of these, the granite hills to the east of the Wadi el Araba are seen to their bases. Close to the Mufraq, in the Wadi el Radadi, near where it leads off from the plateau, is the Thamelet el Radadi. This well is under a steep cliff and the water is some three or four metres below the surface, and is limited in quantity. In October there was no water. Following the Darb Ghaza, the road passes through the somewhat circular chain of hills knowfn as the Gebel Homra from the red fine-grained rocks of which it is formed. In the middle of the chain is a considerable open plain. On emerging from these hills, the great open plain of the Gerafi and tributary wadis is reached, and from here for 50 kilometres the road is almost level with a great stretch of barren land to the west, and a series of low limestone hills to the east.

The northwards road from the Mufraq el Aqaba passes to the east of the Gebel Homra. At the Gebel Abu Alalik a broad and well-beaten road passes over the Nagb el Rakhama and descends steeply to the Wadi el Araba. After passing the Gebel el Homra, an easy track leads westwards between the Gebels Homra and Safra to join the main Darb Ghaza. The Gebel Safra (yellow hill) presumably takes its name from the contrast it presents to the Gebel Homra (the red hill). Another path leads up a very steep track into the Wadi Bir Said, and from here skirts the summits of the precipitous ravines which lead down the escarpment to the Wadi el Araba. The Bir Said was dry in June.

The country through which the road winds is hilly, and the heads of numerous wadis tributary to the Wadi Gerafi are crossed. After passing under Gebel Um Quf, the road descends slightly into the Wadi el Egfi, and crosses the wide open area at the head of it. This wadi was formerly cultivated by the Haiwat Arabs, but little trace of agriculture was seen. The road ascends again on to the main plateau at Ras el Qeradi. Some four kilometres to the right of this is the Thamelet el Ghabia which lies in a tiny gorge through which the wadi of the same name joins the Egfi. The gorge is a beautiful specimen of flint of a deep blue colour. The water merely consists of a shallow pool, which at the time of our visit was only a few inches across, in the gravel in the bed of gorge. It took all night to fill three 10-gallon fantasses and water three or four camels.

From the Ras el Qeradi the country slopes evenly and gently to the Wadi el Gerafi across an open gravel covered plain. This wadi drains a large area of country to the south and west. It descends eastwards eventually reaching the Wadi el Araba. The sele (watercourse) of the wadi is some two hundred metres across, and is covered with wadi shrubs, often two or three metres high. At various points along its length water collects after rain. In the part visited by the Commission, there are, within a few kilometres, the Mashash Kontilla and Mashash Baqar, both dry in June 1906, and the Thamelet el Swelma, consisting of two or three deep wells in the gravel of the wadi bottom, and affording a limited supply of clear and perfectly sweet water. This thamele is not in the Wadi el Gerafi itself, but a few hundred metres up the tributary Wadi Khadakhed. The Mashash Kontilla is to the south of the sele of the Gerafi, under a low hill some fifty metres in height which commands an extensive view of the open Gerafi plain. A few gazelle were seen between the Mashash el Kontilla and the Thamelet el Swelma.

Leaving the Kontilla, the Darb Ghaza ascends the long shallow Wadi

Rod el Homara, and then descends sharply by a white limestone escarpment into the Wadi el Oheiqba. To the west of this tributary of the Qeraia rise the conspicuous twin hills of the Gebel Oheiqba. Another track leads up the gravel-covered slope to the north of the Gerafi, by the Wadi Um Halluf. This area is at times extensively cultivated, but apparently the insecurity of desert crops against raids interferes considerably with agriculture. At the top of the Um Halluf the track descends into the Wadi el Qeraia, crosses this and then, after rising out of the wadi, traverses the head of Wadi Khoraish by a precipitous and dangerous path along an almost vertical cliff, and then descends into Mayein by a long and gentle decline. To the east of this track from the Gerafi rises the Gebel Semawi, the beginning of a great natural barrier which runs from the Gerafi as far as Birin, and which consists of the Semawi range and the so-called Gebel Maqra and its northward extension. This series of hills forms the watershed between the tributaries of the Wadi el Arish and the wadis of southern Palestine.

From the Wadi Oheiqba the road enters the wide plain of the Wadi el Qeraia. The southern boundary of this wadi is formed of a steep limestone cliff and some water is found in it after rains, but at our visit the wells were quite dry. Soon after passing the sele of the wadi, a camel road leads off to the right from the main Ghaza road which runs nearly straight northwards, passing to the west of the Gebel Areif. The branch road slowly ascends at an easy gradient the northern boundary of the Wadi el Qeraia, and, after crossing the small wadis Irqan and Khoraish, descends sharply into the Wadi Mayein, and leads straight to the Biyar (wells). These lie in the centre of a plain which is some 1½ kilometres across, and is surrounded on all sides by hills. The Wadi Mayein enters this plain on the north-east, and leaves by the west. In the rocky side of the valley about two kilometres above the principal wells is a cave in which water can be heard trickling, and from which numerous goats and sheep from the country to the north-east are watered. The Biyar Mayein are vertical shafts in the centre of the plain. The water from them is clear and sweet. Besides these, there are one or two wells in the lower part of the valley under the Gebel el Areif, and there seems little doubt that water could be obtained from any place in the wadi. From all sides paths descend to the wells. From both north and south are branch roads from the Darb Ghaza. Another leads over a steep pass from the wadis Gefi and Lussan, whilst a fourth comes direct from the Wadi Um Halluf, as already described. In the Wadi Mayein, particularly to the west of the wells, the valley is laid out in terraces with rude dams of stone crossing the valley. This is the usual mode of cultivation in this part of the desert, the seles following the winter rains passing from one terrace to the next. The principal crop appears to be barley, whilst tobacco is also grown. The luxuriant desert vegetation seen in the Wadi el Gerafi is almost entirely absent from this and the neighbouring wadis. So much is this the case that the camels of the expedition had to be taken ten kilometres away over a very rough track to graze.

Gebel Areif el Naqa is a most conspicuous conical hill visible for many miles to the south and west, is a greatly-contorted mass of limestone in striking contrast to the evenly-bedded rock which forms the great mass of hills to the east. The hills from which the wadis Mayein, Lussan, Gefi and Khoraisha drain are called, in most maps, the Gebel el Maqra, though this name was entirely unknown to our guides, who called it the Gebel Khoraisha. It appears to be a great plateau of limestone intersected and drained by steep-sided wadis. In the Wadi Lussan some camels are bred.

The heads of the wadis coming from the plateau are very precipitous and exceedingly difficult for loaded camels. From the plateau a vast stretch of country is seen in all directions, though it was mid-day when the summit was visited by the Commission, and vision was consequently imperfect. To the south, the plateau overlooks the Gebel Semawi, the wadis Qeraia and Gerafi, and the granite hills to the east of the Wadi el Araba. To the west, a great stretch of the Wilderness of Tih is seen, and to the north, the view extends over the lower plateau, cut by the Wadi Quderat and other wadis, to El Auga and the Qarn hills.

Two roads lead northward from Mayein to the Wadi el Gefi. The easier one passes down the Wadi Mayein under the shadow of the Gebel Areif and then crossing the Wadi Lussan, joins the main Darb Ghaza, and enters the broad plain of the Gefi after penetrating the low chalky hills which form the watershed of the Wadi Gerur. The other, a rather difficult road, leads by a fairly level but very rough path under the conspicuous cone of the Gebel Meraifiq directly into the Wadi el Gefi. On the way is passed the Bir Um Radim, the water of which was stagnant and covered with a green slime and was said by the guides to be poisonous.

The Wadi el Gefi and subsidiary wadis form a large open plain with hills rising sharply from it on three sides. To the north lies the low plateau of the Gebel el Ain with four conspicuous peaks where the road crosses from the Wadi el Gefi to the Wadi el Ain. To the east rises the much more imposing plateau of the Gebel Maqra, and to the south the Gebel Meraifiq peak and the long and flat Gebel Oneiqa. The whole of the plain of the Gefi is under cultivation, barley, tobacco and durra forming the crops. The Ain Qadis, from which the Bedawin obtain their water, is about one kilometre up a narrow and steep-sided wadi, which leads precipitously down from the Gebel Maqra. The Ain consists of two or three pools which are kept constantly filled from a spring in the side of the wadi, and overflow to form a stream a metre or two wide, which has entirely disappeared in the wadi bottom after some two hundred metres. The Commission reached the Ain Qadis in June, and, though there had been little rain the previous winter, there was an abundant supply of water. Palmer, who visited the place in February, says that the spring is really a "themele" overflowing only in the rainy season, but he must have been misinformed with regard to the nature of the spring, as it is certainly not a "themele" in the sense in which our guides used the word. The following are the main divisions into which the various water supplies are divided:—

(1) The Ain, with water flowing from a spring.
(2) The Bir, a well with perennial supply.
(3) The Thamele, a well which contains water only after rains, and
(4) The Mashash, a surface pool containing water after rains, and rapidly drying.

In the case of the Ains Qadis, Quderat and Qoseima, a considerable supply of water was flowing in June, and was used by many hundreds of sheep and goats.

It may perhaps be recalled that Palmer * identifies the plain of the Wadi el Gefi with the Mosaic Wilderness of Kadesh, and the Ain Qadis with the Waters of Meriba.

From Ain Qadis the route of the Commission lay along the northern side of the Gefi plain and joined the main Ghaza road where this enters the Wadi el Ain. The wadis grouped together under this name come down from a flat plateau to the east and at their confluence form an open plain. Before leaving the limestone plateau, the wadis cut through it in deep narrow gorges with almost vertical sides. The Ain Quderat is in the wadi of that name, and is distant about an hour's ride from Ain Qoseima and the Ghaza road. A considerable stream of water proceeds from it, and the bottom of the valley is covered with

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* "The Desert of the Exodus," by E. H. PALMER. London: 1871.

a rank growth of rushes. The water is said to be exceedingly unwholesome and little attempt is made at cultivation, though there are many remains of ancient dams and reservoirs. Rock pigeons abound in the wadi. Ain Qoseima is the most important spring in the neighbourhood. It is somewat remarkable that Palmer[*] describes this also as merely "a few themâil or shallow pits." Certainly in June 1906 an abundant supply of water was springing out of the ground, and it was evidently the main source of water for the neighbouring people. For the first time after leaving Aqaba, a considerable number of people were seen engaged in ordinary domestic duties. In the mornings the people brought their flocks and herds down to water, and for hours women were engaged in filling girbas for transport to their tents. The neighbourhood of the Ain is very foul from constant and unregulated recourse to the spring.

The valley of the Wadi El Ain and dependent wadis is a large open space about six kilometres across from N. to S. and from E. to W. The whole of it is under cultivation, and in it and also in the Wadi Quderat are numerous ruins of masonry dams and houses. Proceeding northwards from Qoseima, the Darb Ghaza leaves the Wadi el Ain by the Ras el Sram and then follows the wadi of the same name. A short distance east of the road is Birin. Here are several wells built in masonry with numerous troughs for watering the animals brought down to the wells. These troughs have evidently been made by hollowing out stones from the cylindrical columns of the church of El Auga. The Wadi Birin is largely cultivated and in it are several butma trees. On the hills in each side of the wadi are numerous ruins.

The road to Rafa followed by the Commission branches off from the Darb Ghaza in the Wadi Sram. The Darb Ghaza proceeds in a north-easterly direction. The Rafa road crosses some low hills and descends into the wide and open plain of the Wadi Hanein or Hafir and, passing on the left the southward escarpment of the Gebel Um Hawawit, leads through the ruins of El Auga to the wells.

El Auga has been fully described by Palmer, and the time at the disposal of the Commission did not allow of a detailed examination of the ruins. The principal of these consist of a castle and a church standing on a low hill which commands an extensive view over the plains of the Wadi Hanein. For kilometres around, the land is covered with the ruins of what must have been a considerable town. The outlines of the gardens and houses are all clearly visible, and on the hills remain vast numbers of "telelat el enab" or mounds on which grape vines were trained. In the valley below the hill are three wells. Two of these are now filled up, but the third provides the Arabs with an abundant supply of water. It is remarkably well built and lined with good ashlar masonry. All the wells were formerly supplied with saqias (water-wheels) but at present the water is obtained by lowering on a rope a skin bucket loaded with a stone. The water is about twenty metres below the surface, and the muscular arms of the women who do most of the water-raising testify to the arduousness of the work. The country round, which formerly must have supported many inhabitants, is now entirely bare.

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[*] *Loc. cit.*

On leaving El Auga, the region of sand-dunes is at once encountered, and as far as the sea nothing but sand is seen except for the low range of the Qarn hills forming the northern boundary of the Wadi el Abiad for a few kilometres west of El Auga. This range terminates westwards in a very conspicuous cone called the Khashm el Qarn, which forms a very conspicuous and useful landmark, and from which a very extensive panorama of the sand-dune area is obtained. The paths across the sand are very difficult, the sand being very loose, and the sides of the dunes steep. Small patches of durra and tobacco lead a struggling existence in the sand, and a considerable number of camels are bred in this area. Water seems to be entirely absent, and the camels have to be taken weekly fifteen or twenty miles to the nearest wells.

This area is divided by the Arabs into districts—el Gura, el Murabaa and the like. The boundaries of these are definitely known to the Arabs though there is nothing to mark them on the surface of the ground. On approaching the sea the surface becomes more compact and cultivation much more extensive, until twenty kilometres from Rafa the whole country is utilized for agriculture. Numerous tracks are passed coming in one direction from Ghaza and in the other from the Rafa wells which furnish the country with water. Small clumps of trees are also fairly common. Ten kilometres from Rafa, the road which has been on the whole gradually descending from El Auga, rises over a low line of sandy hills which runs parallel to the shore line, and from there a gentle decline leads to Rafa. Off the tracks the going is bad as the ground is literally honeycombed with rat holes and at every step the camels break through the rotten ground. From the greater part of the road the sea is invisible. This is due to the line of dazzling white sand-dunes which form a fringe a kilometre wide skirting the shore for many miles.

At Rafa itself, there is a single well providing a plentiful supply of water. Other wells near by are those of Rafyh, built in masonry and much used by the neighbourhood, and several wells on the shore line. Near the Rafa well is a pomegranate tree, and a number of fig trees were met with in hollows in the sand-dunes. Large numbers of excellent battikh (water-melons) are grown, and other crops are barley, tobacco, and durra. The telegraph line from Egypt to Syria passes close to the Rafa wells. For a considerable distance from the shore the sea is very shallow, and landing from steamers through the surf is difficult, and at times impossible.

Speaking generally, it may be said that the boundary line, after rising from the Gulf of Aqaba to the top of the plateau at the Mufraq el Aqaba, runs along the escarpment of the plateau as far as Ras el Qeradi. Thence it crosses the Wadi el Gerafi and follows the line of the great barrier mentioned above and consisting of the Gebel el Semawi, el Maqra, and Gebel el Ain. From here it runs in a nearly straight line, leaving Birin and El Auga in Turkish territory, and continues across the sand-dunes to Rafa.

NOTE.—Place names in the above and on the map are transliterated according to the custom of the Egyptian Survey Department. In particular:—

ج is transliterated—G.
ع is ignored.
ق is transliterated—Q.
غ is transliterated—GH.

It should however be noted that:—

ج is pronounced like—J in jet.
ق „ „ „ G „ get.
غ „ „ in the true arabic manner.

METHODS USED IN THE TOPOGRAPHICAL SURVEY.

The system of work varied considerably according to the country passed over and the speed demanded. The instructions received from the Commissioners were to produce a rough sketch map of the country to enable the boundary to be subsequently identified, and to fix as well as possible all sources of water-supply. On arrival at Aqaba, the coast-line, the road up to the mufraq of the Ghaza and Suez roads, and the Ghaza road through Gebel el Homra were plotted by a tacheometric traverse, the azimuth being checked three times against Mr. Wade's astronomical azimuths, and frequently by magnetic azimuths determined with a prismatic compass. On leaving the mufraq the work was necessarily of a rougher character. Throughout it divided itself into two divisions, the first being the reconnaissance of Mr. Wade's astronomical positions, and the second the topography. In the first part the object was to select suitable points, about 20 kilometres apart, as closely as possible on the line between Rafa and the Marashash corner of the head of the Gulf of Aqaba, such that at each point the previous one was visible and an extensive view secured to the north-west. In one or two cases, this was not possible without much delay. Thus the Gebel el Safra was chosen as an astronomical station in spite of the fact that the view northwards was limited. This was done because it was risky to venture further, it being more than doubtful whether the previous station (Ras el Radadi) would again be seen. This rendered the point on Um Quf necessary, and, as the distance from Gebel el Safra was short, the length was determined by a base-line and angles. A chained base was not feasible owing to the nature of the ground, so the base-line was measured by the tacheometer. The observations are given on p. 38.

From Um Quf to the Gerafi the country was surveyed partly by time and pace traverse, correcting the position by compass observations back to Um Quf and Ras el Qeradi, and partly by tacheometric base-lines and triangulation, oriented by compass azimuths on to these marks. The survey away from the line was done partly by intersection, and, of course, partly by interrogating the guides and making models of the country on the ground with sand and stones. Much time was lost by this, and the relationship of wadis and hills had to be gone over time after time before correctness could be assured. An absolute essential for rapid work, which unfortunately was in the present case lacking, is a knowledge of the Bedawi dialect, and in particular a detailed acquaintance with the meaning of geographical terms, e. g. those for watershed, pass, confluence of wadis, small hill, pap-shaped hill, the different forms of water-supply (bir, thamele, mashash), etc.

Good time traverse was difficult owing to the pace at which the ground was covered, and the necessity of making up time by trotting when the surface was suitable. Between the mufraq above referred to and Mayein, there is not in summer sufficient water to keep even a small camp supplied, and the absence of arrangements for branch camps made frequent intercourse with head-quarters almost a necessity.

The work from the Gerafi to the beginning of the sand-hills was the easiest and best done. There are three or four prominent peaks which, once fixed, were exceedingly useful. Thus, the district between Mayein and the Gerafi was largely done on to two hills—Gebel Areif el Naqa and a spur of the Semawi range, the line joining the two being almost at right angles to the line of the boundary. The system adopted was to ride on a camel and at frequent intervals to descend and take bearings on to these hills. Then, having oriented the plane-table, shots were taken on to other features. It may be remarked that in this work baggage camels were dispensed with, all supplies and instruments being carried on the riding camels.

After leaving Mayein, the position of a prominent peak, Gebel Oneiga, was determined, and utilized as a point on which to base the survey of the neighbouring country. Whenever possible, the tacheometer was taken with the party, as its application to the measurement of base-lines was found exceedingly convenient. Succeeding hills used as fundamental points were Ras el Ain and Khashm el Qarn.

It may be mentioned that in the 25 days of the survey some 700 kilometres were covered by camel.

A summary of the water-supply is attached.

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[*] A good vocabulary of such names would be very valuable for those engaged on desert work.

THE WATER-SUPPLY OF THE SINAI BOUNDARY.

I. *Aqaba.*—Abundant supply from numerous wells close to the shore-line.

II. *Marashash.*—No good supply of water. The Turkish outpost was supplied by cart from Aqaba.

III. *Taba.*—The old well filled in. The new well is brackish, and the water three or four metres below the ground.

IV. *Bir Qattar.*—Water always. Sufficient for 20 to 40 men. Not visited.

V. *Thamelet el Radadi.*—Some distance below the ground under an overhanging rock. Difficult of access and watering very slow. No water when the commission returned in October.

VI. *Bir el Said.*—No water when visited.

VII. *Thamelet el Ghabia.*—When visited consisted of a pool about ten inches across. Not sufficient for more than five camels and men.

VIII. *Mashash el Kontilla.*—Water after rain.

IX. *Thamelet el Swelma.*—Several wells sunk in the gravel. The water, of excellent quality, was about three metres below the ground but in June there was very little water and in October none.

X. *Mashash el Baqar.*—Water after rain.

XI. *Mayein.*—Several deep wells of good water. Always plentiful supply. In the eastern well the water was flowing through the well. Bir Beda was dry when visited.

XII. *Bir Um Radim.*—Surface-well covered with green slime. Said to be poisonous.

XIII. *Ain Qadis.*—Flowing water. The surroundings of the Ain very foul.

XIV. *Ain Quderat.*—Flowing water of good quality. The wadi is said to be unhealthy.

XV. *Ain Qoseima.*—Flowing water of good quality. Neighbourhood foul.

XVI. *Birin.*—Several wells lined with rubble.

XVII. *El Auga.*—One well in use. Well built in ashlar. Water 15 metres below the surface. Designed for use with a saqia which could easily be fitted. Formerly many wells, now choked.

XVIII. *Rafa.*—Plentiful supply. One well lined with masonry.

XIX. *Rafyh.*— do. do.

XX. *Coast.*—One or two wells on the Egyptian side of the boundary.

B. F. E. Keeling.

MEMORANDUM

ON THE EXCHANGE OF TIME SIGNALS WITH RAFA, AND ON THE LONGITUDE OF RAFA.

Before the delimitation commission left Cairo, it was arranged that the Egyptian Telegraph Administration should extend their line from El Arish to Rafa with a view to the exchange of time-signals between Helwan and the latter place, and by telegram received from Rafa it was arranged that the exchange should take place on the evening of June 30. A rehearsal at the Observatory * on the previous day showed that the apparatus was in good working order and on the evening of the exchanges no hitch took place after the apparatus had been fitted together. The method adopted was to actuate the chronograph pen by two relays, one worked by the current to Rafa, the other by the current made and broken by the Observatory mean time standard clock Dent 1914. Thus the seconds were recorded on the chronograph paper which also showed all signals sent from or received by Helwan. As a precaution in case the chronograph should fail, the times of despatch and arrival of signals were observed by direct comparison with the clock, but these were not required. The signals were sent by hand, using the ordinary Morse key of the telegraph apparatus.

Three groups of seven signals were sent from each end, those of each group being at intervals of twenty seconds.

The clock was rated immediately before and after the time-signals. Five stars were observed with the transit instrument, but in the first set the pen of the chronograph ceased to record just before the fifth star came on to the wires.

The longitude of Helwan.—In 1904 the transit instrument at the Observatory was connected by triangulation with the station on the Moqattam Hills which was occupied by the British Expedition to observe the transit of Venus in 1874, and the longitude of which was at that time determined by exchange of telegraphic signals with Greenwich. †

The concluded longitude of the Transit of Venus Station is	31° 16′ 33″·6 E.
The triangulated difference of longitude to Helwan is	3′ 58″·0 E.
Hence the longitude of Helwan is	31° 20′ 31″·6 E.

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* The actual arrangements were made by the Acting Superintendent, Mr. P. A. Curry.

† See Report on the Observations of the Transit of Venus (London 1881); p. 288.

Transits at Helwan.—The best observer at the Observatory took the transits. Times were recorded on the chronograph controlled by the mean time clock. The stars of the two sets and the means of the times of transit over the five wires are shown in Table I. The collimation constant *c* was determined independently for each set, and the remaining constant *n* was found from the clock errors corrected for level and collimation.

TABLE I.—TRANSITS AT HELWAN 1906, JUNE 30.

FIRST SET.

STAR.	Clock time of transit over mean wire.	Δt for Dent 1914.
	h. m. s.	h. m. s.
η Boötis	7 13 23·56	−17 23 10·49
τ Virginis	20 01·57	10·52
κ Virginis	31 00·88	10·59
α Boötis	34 30·18	10·59
		Mean −17 23 10·55

$b = -\,0^{\mathrm{s}}{\cdot}02 \qquad c = +\,0^{\mathrm{s}}{\cdot}30 \qquad n = -\,1^{\mathrm{s}}{\cdot}06$

SECOND SET.

STAR.	Clock time of transit over mean wire.	Δt for Dent 1914.
	h. m. s.	h. m. s.
γ Ursae Minoris	8 43 54·64	−17 22 55·29
α Coronae	8 53 39·02	56·02
μ Serpentis	9 07 36·33	55·81
δ Scorpii	9 17 38·27	55·90
η Draconis	9 45 34·25	56·32
		Mean −17 22 55·87

$b = -\,0^{\mathrm{s}}{\cdot}02 \qquad c = -\,0^{\mathrm{s}}{\cdot}52 \qquad n = -\,1^{\mathrm{s}}{\cdot}22$

From these are deduced the following errors for Dent 1914:—

		m. s.
From the First Set... ...	Clock slow on local mean time	5 23·48
„ Second „	„ „ „	5 23·29
	Mean	5 23·39

The simple mean has been taken because although there were fewer stars in the first set, their internal agreement is better than in the second set. And further, about this time, considerable variations were found in the collimation constant of the transit, which were subsequently traced to the fact that the lens of the object glass was loose. The clock error is affected by the personal equation of the observer, which there was no opportunity of comparing with that of Mr. E. B. H. Wade, who observed at Rafa. It is thus of little practical utility to attempt any further elaboration of these two corrections to the clock at Helwan.

Observation for local time at Rafa.—The method of procedure adopted has been fully explained and the observational data given in the earlier parts of this Report (see p. 25).

During the revision of Mr. Wade's calculations in the Computation Office of the Department, it was found that the clock correction deduced by him for watch A[*] did not require correction by so much as 0·02 s. and accordingly his figure has been adopted.

His figures may therefore be written to the nearest 0·05 s., which gives:—

	h.	m.	s.	
Correction to watch	9	00	54·60	slow on L. S. T.
at the watch time...	4	55	03·5	
That is, at local sidereal time	13	55	58·10	

	h.	m.	s.
The sidereal time of Greenwich mean noon was... ...	6	30	34·39
Acceleration for longitude 2 h. 16 m. 57 s.			22·50
Local sidereal time of local mean noon...	6	30	11·89
The sidereal interval since mean noon was...	7	25	46·21
Retardation...		1	13·03
Mean time	7	24	33·18
Watch time...	4	55	03·50
Watch slow on local mean time	2	29	29·68

It will be observed that this value differs from that employed by Mr. Wade owing to his having adopted an erroneous value of the longitude in finding the acceleration of the sidereal time of mean noon, and the clock error now found exceeds his by 1·38 s. There was a compensating error in the transit computations, which reduces the ultimate effect on the longitude to 0·9 s.

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[*] See p. 25.

As already mentioned, no opportunity was available of comparing the personal equation of the observer at Helwan with that of Mr. Wade, so that the longitude determination is uncertain by the difference of these two quantities, and it is also affected by the equation of method, which involves Mr. Wade's personal equation in giving and receiving signals.

The Time Signals.—The signals were sent from and received at Helwan and Rafa at the times shown in the table.

TABLE II.

A.—Sent from Helwan. Times by Dent 1914.

	First Set.			Second Set.			Third Set,		
	h.	m.	s.	h.	m.	s.	h.	m.	s.
1	8	7	0·00	8	16	0·15	8	24	0·20
2		7	20·20		16	20·20		24	20·15
3		7	40·20		16	40·15		24	40·15
4		8	0·20		17	0·20		25	0·15
5		8	20·20		17	20·15		25	20·15
6		8	40·20		17	40·15		25	40·15
7		9	0·20		18	0·10		26	0·15
Means...	8	8	0·17	8	17	0·16	8	25	0·16

B.—Received at Helwan. Times by Dent 1914.

	First Set.			Second Set.			Third Set.		
	h.	m.	s.	h.	m.	s.	h.	m.	s.
1	8	11	56·20	8	19	56·00	8	27	56·05
2		12	16·10		20	16·00		28	15·95
3		12	35·95		20	36·00		28	35·90
4		12	56·05		20	56·15		28	55·95
5		13	16·15		21	16·00		29	16·00
6		13	35·90		21	35·75		29	35·95
7		13	56·00		21	56·00		29	56·00
Means...	8	12	56·05	8	20	55·99	8	28	55·97

C.—RECEIVED AT RAFA. TIMES BY WATCH A.

	First Set.			Second Set.			Third Set.		
	h.	m.	s.	h.	m.	s.	h.	m.	s.
1	5	54	29·1	6	3	29·1	6	11	29·1
2		54	49·2		3	49·2		11	49·1
3		55	9·0		4	9·1		12	9·0
4		55	29·0		4	29·2		12	29·0
5		55	49·2		4	49·2		12	49·1
6		56	9·2		5	9·1		13	9·0
7		56	29·2		5	28·9		13	29·0
Means	5	55	29·13	6	4	29·11	6	12	29·04

D.—SENT FROM RAFA. TIMES BY WATCH A.

	First Set.			Second Set.			Third Set.		
	h.	m.	s.	h.	m.	s.	h.	m.	s.
1	5	59	25·0	6	7	25·0	6	15	25·0
2	5	59	45·0		7	45·0		15	45·0
3	6	0	5·0		8	5·0		16	5·0
4		0	25·0		8	25·0		16	25·0
5		0	45·0		8	45·0		16	45·0
6		1	5·0		9	5·0		17	5·0
7		1	25·0		9	25·0		17	25·0
Means	6	0	25·00	6	8	25·00	6	16	25·00

When the respective corrections to the two clocks are applied to these, the following table of corresponding times is deduced:—

TABLE III.

	First Set.			Second Set.			Third Set.		
	h.	m.	s.	h.	m.	s.	h.	m.	s.
From A	8	13	23·56	8	22	23·55	8	30	23·55
„ C	8	24	58·81	8	33	58·79	8	41	58·72
Rafa Time fast on Helwan Time		11	35·25		11	35·24		11	35·17
From B	8	18	19·44	8	26	19·38	8	34	19·36
„ D	8	29	54·68	8	37	54·68	8	45	54·68
Rafa Time fast on Helwan Time		11	35·24		11	35·30		11	35·32
Means of I and II •		11	35·24		11	35·27		11	35·24

	h.	m.	s.
General Mean. Rafa Time fast on Helwan Time...	0	11	35·25
But the longitude of Helwan is east of Greenwich...	2	5	22·1
Hence the longitude of Rafa is east of Greenwich...	2	16	57·35
or **Longitude of Rafa (A. 13.)**	34°	14′	20″·2 E.

As the value found by Mr. Wade in the field was 34° 14′ 7″·2 (see p. 36), all the longitudes of the map signed by the Commissioners* require a correction of + 13″·0, with the exception of the unimportant Point A. 10. the correct longitude for which is deduced on p. 86.

Controls on the longitude.—By methods already explained, Mr. Wade found the following difference of longitude:—

Point A. 2. east of Rafa	0° 46′ 19″
The map on the scale 1 : 100,000 shows that Aqaba Fort is east of A. 2.	18″
Hence Aqaba Fort is east of Rafa...	0 46 37
But the longitude of Rafa is	34 14 20
Hence Aqaba Fort is...	35° 00′ 57″
Mr. Wade also determined the longitude of Point A.1. by chronometric difference from Suez to be...	34° 54′ 42″ †
and Aqaba Fort is east of A.1....	5 42
Hence the longitude for Aqaba Fort is	35° 00′ 24″

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* See pp. 36, 48.

† See p. 36.

Other values for the same fort are given as follows :—

Red Sea Pilot (British Admiralty)	35° 01′·0
"Pola" Expedition	34° 59′ 18″

In a note on the longitude of points in Suez, it is shown that corrections of + 16″ and + 19″ should be applied to the secondary meridians employed by the British Admiralty and the Pola Expedition respectively. If this is done, the following comparative table of longitudes of Aqaba Fort results :—

1. By the Boundary Commission	35°	0′	57″	E
2. By Mr. Wade from Suez	35	0	40	E
3. By British Admiralty...	35	1	16	E
4. By "Pola" Expedition	34	59	37	E

The first of these is the value used in plotting the map.

It will thus be observed that the first value is in good agreement with the corrected British value and with that deduced by Mr. Wade from Suez.

Revision of Field Computations.—As already mentioned, the astronomical computations were revised in the Computation Office with the result that in addition to the error already indicated, only one more was found, namely in the position of Point A. 10. By a clerical error the longitude of this point (which was not afterwards employed in fixing the boundary) originally adopted was 34° 26′ 15″·7 E. Its true position should be, East of Rafa ... ... 11′ 47″
or ... ... 34° 26′ 8″

The latitude remains substantially the same, and the change in the position of A. 10. *bis* amounts to only 0″·2 in longitude, which is insignificant.

LONGITUDE POINTS IN SUEZ.

There are in Suez four points whose longitudes from Greenwich have been determined, or which have served as points of origin of other longitudes. These are:—

(1) The point occupied by Mr. S. Hunter during the Transit of Venus Expedition in 1874. This will be denoted by H.

(2) The point employed by Lord Lindsay as origin for his determination of the longitudes of Aden and Mauritius. This will be denoted by L.

(3) The point used by the British Admiralty as secondary meridian for the Red Sea. This will be denoted by A.

(4) The point used by the Expedition of the Austrian ship "Pola" as origin of longitudes in the Red Sea. This will be denoted by P.

(1) Point H.—This is described in the Transit of Venus Report, p. 335, as being 91 feet 8 inches (28 m.) from the S. E. corner of the Khedivial Chalet, and 48 feet 6 inches (15 m.) from the flagstaff.

The longitude depends on that of the Transit of Venus Station on the Moqattam Hills and on telegraphic exchange of signals on four nights. Major Tupman says that this longitude must be considered to be as satisfactorily determined as that of Moqattam.

The concluded value, corrected for personal equations of observing stars and of giving and receiving signals, is:

	h.	m.	s.
H east of Greenwich	2	10	13·17
or	32°	33′	18″

(2) Point L.—On his way to Mauritius to observe the Transit of Venus in 1874, Lord Lindsay determined telegraphically the difference of longitude between Aden and a point in Suez, which on the return of the party was connected with Point H. The two points were again connected in 1877 by the officers of the Survey of India, who found:[*]

	h.	m.	s.
L. west of H			0·025
Longitude of H	2	10	13·17
Longitude of L.	2	10	13·14
or	32°	33′	17″

Sir David Gill, F. R. S., in conjunction with Professor Auwers, made a separate determination of the longitude of L. in 1875.[†] The longitude of Alexandria (Hotel de l'Europe) east of the central tower of Berlin Observatory was found to be:—

	h.	m.	s.
	1	5	58·897
Berlin east of Greenwich [‡]	0	53	34·91
Alexandria east of Greenwich	1	59	33·807
He found L. east of Alexandria	0	10	38·923
So that L. is east of Greenwich	2	10	12·73
or	32°	33′	11″ [§]

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[*] Great Trigonometrical Survey of India. Vol. IX, Part II, p. [109].

[†] Dun Echt Observations, Vol. III.

[‡] Berlin Jahrbuch, 1883, pp. 368-9.

[§] This longitude is discussed also in Vol. I, Part 2, of the Annals of the Cape Observatory pp. 58-62. These particulars have been kindly communicated by Sir David Gill.

This is 6″ less than the value found from Mr. Hunter's point.

The same series of determinations has been discussed by Dr. Auwers in the Astr. Nachrichten, No. 3180, and again with a slight variation in "Die Venus-Durchgänge 1874 und 1882." On the basis of this second discussion, he finds the longitude of point L to be :—

	h.	m.	s.
L. east of Greenwich	2	10	13·042
or	32°	33′	15″·63

There are thus three determinations for this point L.

(1) That from Mr. Hunter's point :— 32° 33′ 17″.

(2) Gill-Auwers discussed by Dr Copeland :— 32° 33′ 11″.

(3) Gill-Auwers discussed by Dr Auwers :— 32° 33′ 16″.
if the values are rounded off to the nearest second.

The simple mean 32° 33′ 15″ is probably not far from the truth, and, being sufficiently accurate for the present purpose, will be adopted in what follows.

(3) Point A.—This point is the head of the South Mole of Port Ibrahim. Its longitude is given on the Admiralty Chart of Suez Bay (date apparently 1883) as 32° 33′ 12″ E. depending on Alexandria Lighthouse being 29° 51′ 40″ E. The latter depends on Mr. S. Hunter's determination of the longitude of the Hotel de l'Europe in Alexandria in 1874, (see Transit of Venus Report, p. 323), and may be taken as correct to 0·5″ with respect to the hotel.

By measurement on the above mentioned chart (scale 1 : 36,300), it appears that :—

Point A is east of H	12″
Longitude of H	32° 33′ 18″
Longitude of A	32° 33′ 30″

The Admiralty value of A appears therefore to require correction by + 18″, or, if the mean value for Suez H is employed, by + 16″.

(4) Point P.—This was used by the Expedition of the Austrian ship "Pola" during the years 1905-6.

There is a discrepancy between the description given on p. 12 of the Report* and the sketch (opposite p. 130), for, whereas the former says that the Universal Instrument was on the point +, no such point is shown on the sketch. There is, however, a point marked A which, by analogy with the other sketches, probably shows the situation of the instrument. If this is so, then by measurement from the sketch, we have:—

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* Berichte der Commission für Oceanographische Forschungen. Wien, 1898.

P. east of A 485 metres	17"
Longitude of A (from H)...	32° 33′ 30"
Longitude of P	32° 33′ 47"

The position of P utilized by the Pola Expedition [*] was 32° 33′ 26"

From the above calculations, therefore, the longitudes given by the Pola Expedition require a correction of + 21", or with the mean value for the longitude of Suez (H), + 19".

J. I. Craig.

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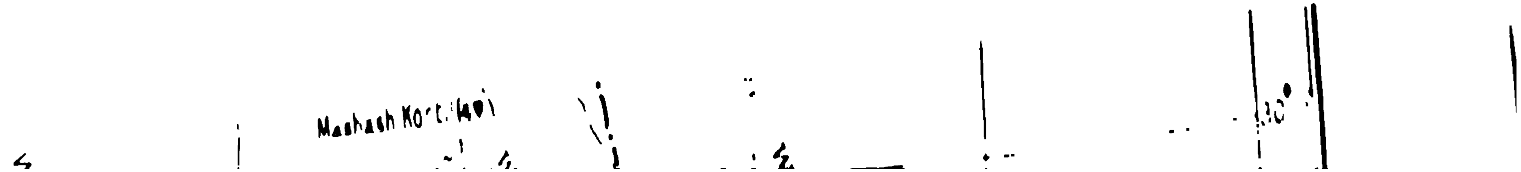
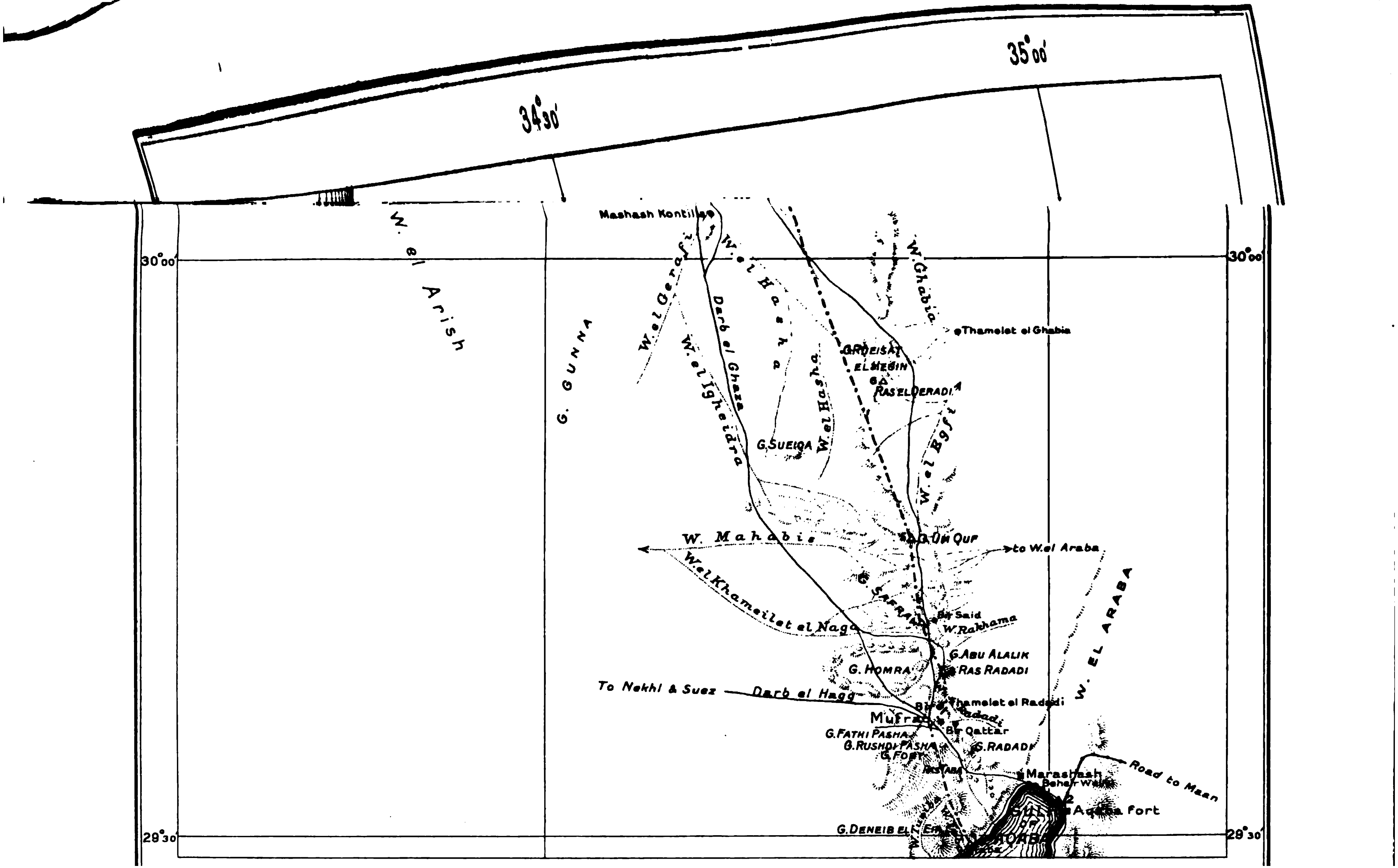
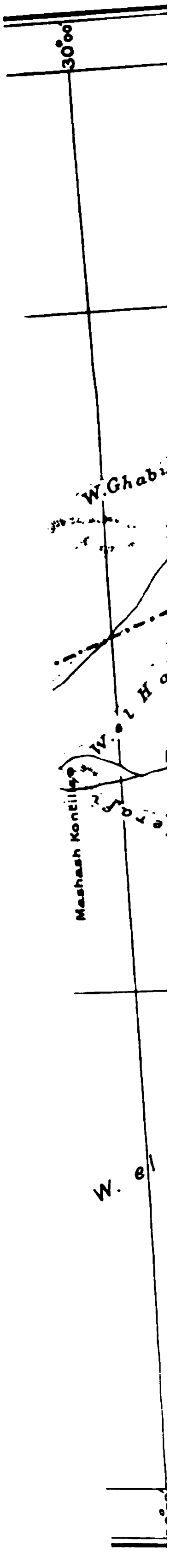
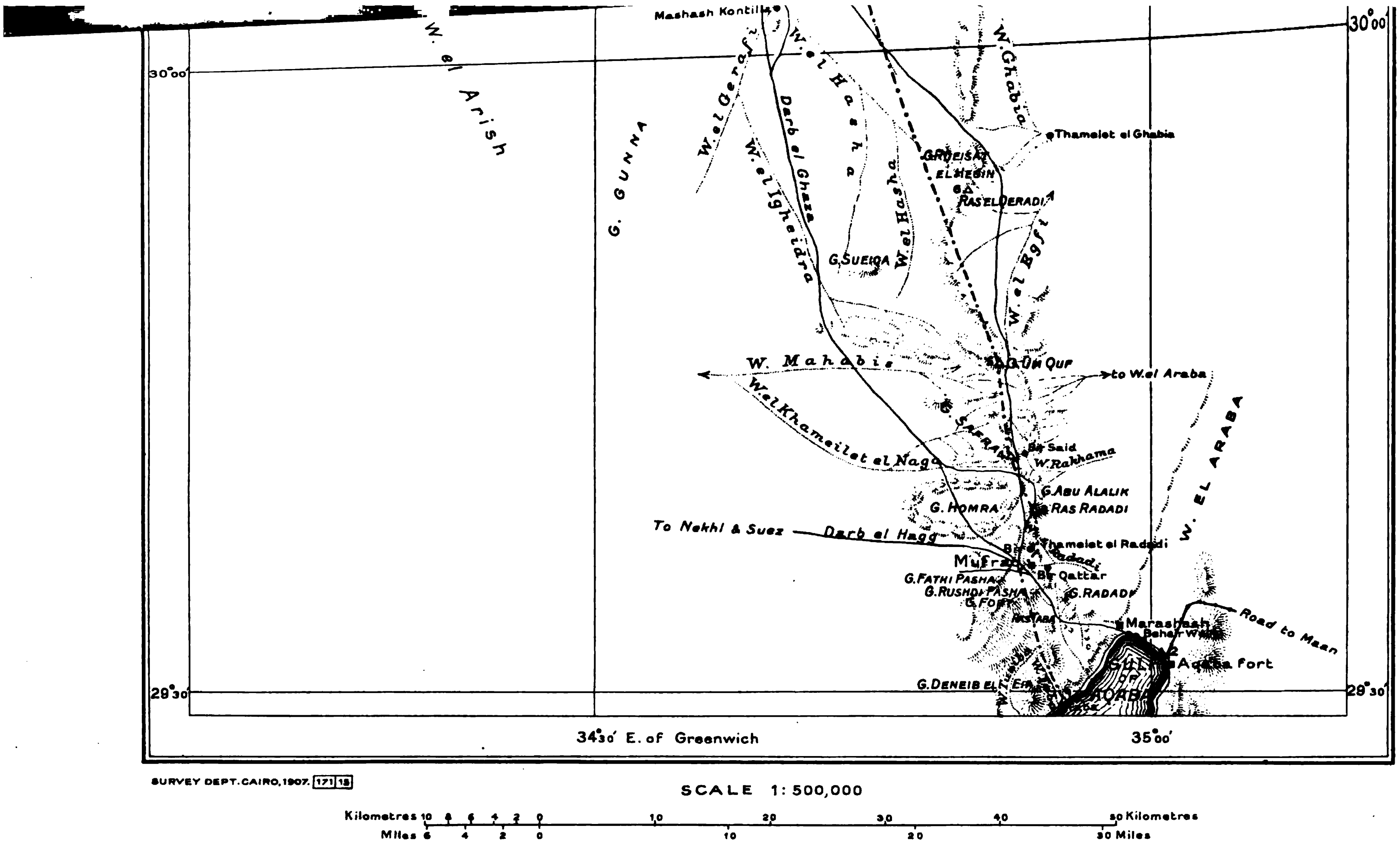
[*] Berichte der Commission, etc., (pp. 4 and 12).


Mashash Ko'c (40)

MAP SHOWING TURCO




30°00'
W. Ghabi
W. el Ha
Mashash Kontila
W. el



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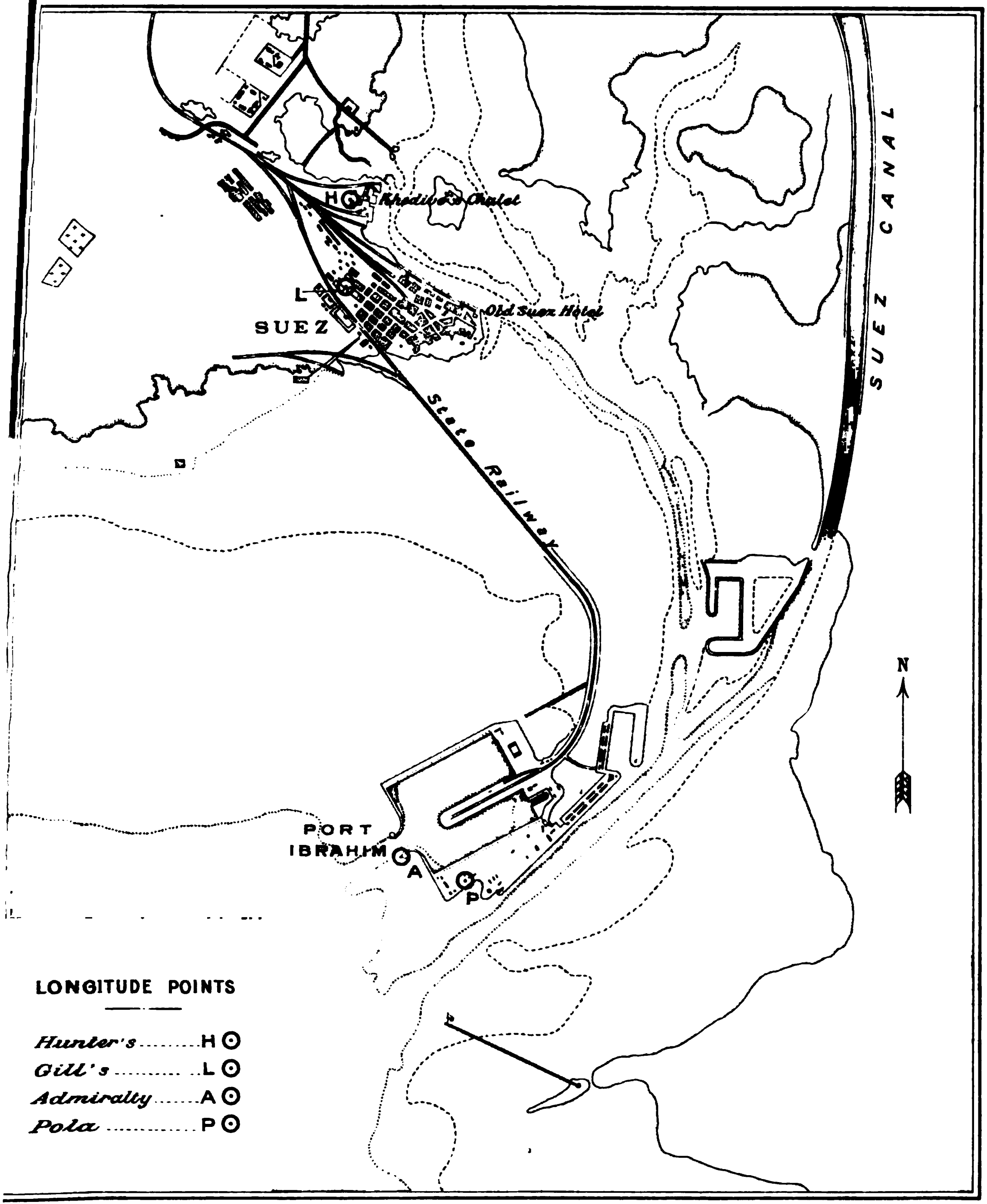
MAP OF SUEZ

(Showing Longitude points).



SURVEY DEP. CAIRO 1908. 843|13

Scale 1: 40,000

400 100 0 400 800 1200 1600 Metres

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Archæological Survey of Nubia, Bulletin No. I.
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